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ABSTRACT

A committee was appointed by the American Electronics Association (AEA) to: (1) study the problem of shortage of engineers, especially computer and electrical engineers; (2) determine the degree of shortage; and (3) recommend how AEA could effectively address the problem. The committee's findings are provided in this three-section report. Section I assesses the status of engineering in 1984, focusing on trends related to the shortage of electrical and computer engineers and ways to improve the situation. Two points made in this section are (1) that while some improvements have occurred in engineering faculty recruitment and retention since 1982, shortages in 1984 remain severe, and (2) that AEA's national effort to improve the faculty situation is "on the mark" and should continue. Section II examines what AEA has accomplished since 1981 and is accomplishing to remedy the situation. AEA organizational infrastructure, AEA's leadership role, establishment of a database, legislative activities (including state legislation related to technical education and to elementary/secondary education), and the Electronics Education Foundation are among the areas considered. Section III outlines and discusses new directions AEA's Engineering and Technical Education Committee recommends should be taken (including various federal and state initiatives). A list of references and supporting documentation are appended. (JN)

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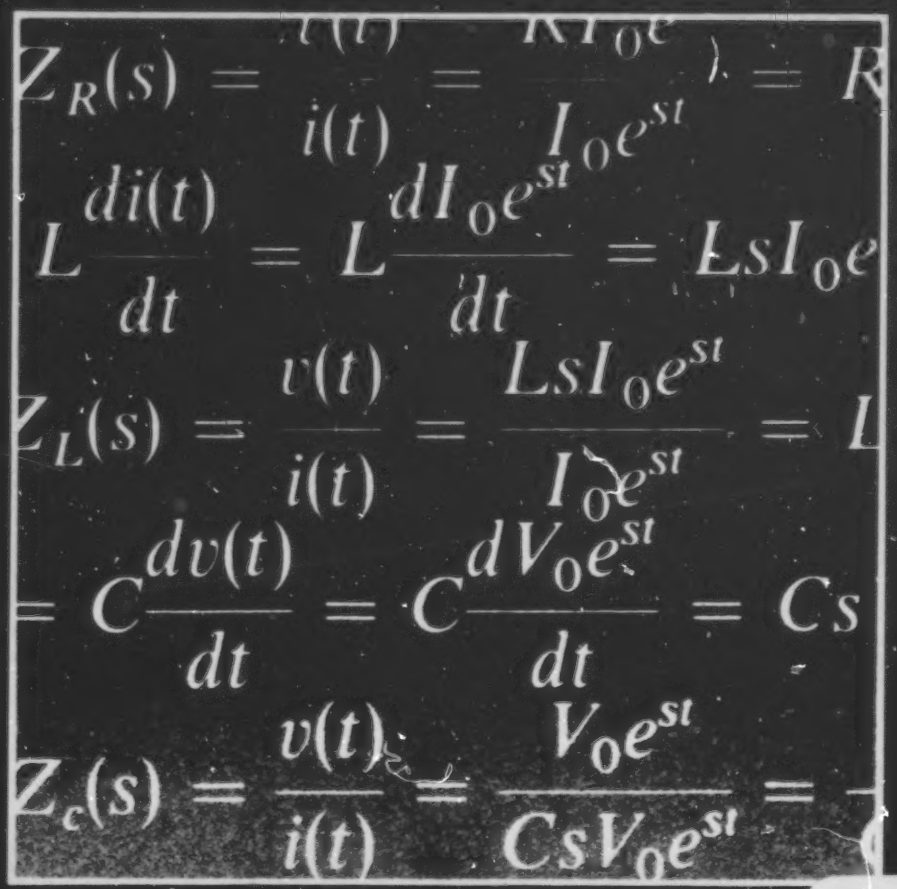
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AEA Status Report on Engineering and Technical Education

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November 1984

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Executive Summary

In June of 1981 the American Electronics Association's (AEA) Board of Directors appointed a select group of industry executives and educational leaders to a Blue Ribbon Committee (Addendum A). The Committee's charge was to study the problem of shortages of engineers—especially computer and electrical—determine the degree of shortage, and recommend how AEA could effectively address the problem.

In September 1981, AEA's Board approved Blue Ribbon Committee recommendations for a nine-point plan of action at the postsecondary level. AEA began its effort recognizing that the problem over time would shift into community college and elementary and secondary (K-12) education. "Industry would need to work to solve it for the long haul."

This report three years later assesses the current state of engineering education (Section I). It catalogs what AEA has accomplished and is accomplishing (Section II). It also outlines new directions AEA's Engineering and Technical Education Committee (Addendum B) recommends be taken (Section III).

The state of elementary and secondary education has captured the concern of educational and industrial groups and state governments. Many are now working on K-12 problems. There is nationwide interest in ensuring development of educated, enlightened citizens who can function in a growing technologically based society. Presently, however, the "best and brightest" high school graduates are eager to pursue degrees in engineering, computer science, and other technical fields. Many are thwarted due to shortages of college faculty, equipment, and classrooms.

Electronics and information technology companies rightfully worry about a special slice of K-12 problems—math and science preparation. Changing demographics will reduce the number of high school graduates. For every four today, there will be only three by 1990. More of these will be females and minorities—two groups historically avoiding math and science courses.

However, the growing magnitude of engineering and computer science faculty shortages warrants AEA's continued major focus. For companies that want to take complementary action to remedy K-12 math and science education, a program is offered in a separate document, "AEA Action Plan for Pre-College Math and Science." Key elements of this K-12 program counterpoint AEA's higher education effort—fellowships to develop new teachers, merit awards to retain good ones, computers to increase instructor productivity, and lobbying for higher faculty salaries and classroom budgets. Companies that want to undertake these activities collectively as an AEA Council must be willing to provide funding for staff coordination.

When AEA began its engineering education program, academicians commonly used a metaphor to describe the major problem. They compared industry's appetite for hiring bachelor degree graduates — which removed them from doctoral study and academic careers — to that of starving American Indians of long ago. To survive the winter these Indians ate the seed corn needed to plant next year's crop. Few now refer to the "seed corn" metaphor, not only because of its overuse but because industry has taken and is taking steps to reverse the situation.

The problem, long in the making, will be long in solving. Individually, and collectively under AEA, electronics and information technology companies can take pride in beginning.

Pat Hill Hubbard
Vice President
Engineering & Technical Education
American Electronics Association
Fall 1984

Summary of Key Points

Section I—Engineering Education 1984 (pp. 1–27)

While some improvements have occurred in engineering faculty recruitment and retention since 1981, the shortages remain severe. Sufficient faculty are a proven key to both quantity and quality of engineering graduates. AEA's national effort to improve the faculty situation is "on the mark" and should continue.

The situation:

- Electrical engineer bachelor degrees (BS/EEs) increased 37 percent since 1980; in 1983, 18,500 BS/EEs graduated—highest number in history.
- Computer engineer bachelor degrees (BS/CEs), on the increase since 1980, dropped by 23 from 1982 to 1983 — a result of too few faculty, not too few students.
- Major forecasting groups predict the following:
  - The National Science Foundation expects a 10 to 15 percent increase in demand for EEs and CEs, and a "severe shortage" of computer science (CS) professionals.
  - The Bureau of Labor Statistics projects EE job growth between 1982-1995 of 65 percent and a CS shortfall of 15 to 30 percent by 1987.
  - AEA companies project annual job growth through 1987 of 10.6 percent for EEs, 16.5 percent for CEs, and 15.2 percent for CS professionals.
- Numbers of qualified high school graduates who want to study engineering and CS remain high. Engineering is now their first choice, CS their third.
- Undergraduate engineering enrollment is at an all time high. Since 1980, EE is up 32 percent and CE 63 percent. However, enrollments are being capped — or reduced at some universities — due to faculty, space, and equipment shortages.
- Faculty shortages continue to be the major problem:
  - Overall engineering faculty vacancy rate improved—from 10 percent of 18,000 full-time positions in 1980 to 8.5 percent of 18,440 in 1983.
  - EE vacancy rate improved between 1980 and 1982 but worsened in 1983; approximately 100 new EE professors graduated to fill 390 vacancies.
  - CE vacancy rate remained steady. Although authorized positions rose 63 percent since 1980, percentage of vacancies remained the same in 1983; approximately eight new CE professors graduated to fill 240 vacancies.
- Major cause of faculty vacancies is inability to attract U.S. citizens with Ph.Ds to academia. Foreigners remain major faculty source:
  - In 1981 and 1982 engineering doctorates given to non-U.S. citizens exceeded those awarded to U.S. citizens.
  - 18 percent of all U.S. engineering faculty in 1982 were foreign; that percentage is slightly higher in CE and EE.

- U.S. citizens avoid graduate study and teaching careers. A study of Tau Beta Pi engineering graduates shows:
  - 28 percent in 1982 preferred industry salaries to graduate study compared to 5 percent in 1977.
- Fewer and fewer Ph.Ds select teaching careers: 21 percent of new Ph.D/EEs in 1982 wanted to teach compared to 33 percent in 1979.
- Since 1981, the Ph.D. pool from which faculty are drawn has improved in EE, with 25 percent — or 125 graduates — more; it has worsened in CE, with 40 percent — or 69 graduates — less.
- Faculty shortages are impacting educational quality:
  - Engineering enrollments were up 100 percent between 1972-1982 but faculty numbers rose only 10 percent. Student-to-faculty ratios increased 32 percent over the last five years.
  - Between 1978-1983 the Accreditation Board for Engineering and Technology awarded a full six-year accreditation to 50 percent fewer engineering programs; those not accredited almost doubled.
- A 1984 NSF study found one-fourth university research equipment obsolete. Universities are rejecting equipment donations due to lack of service and repair funds; some $15 million is needed to make all EE and CE equipment usable for an academic year.
- Antiquated research facilities are causing loss of research dollars. Average capital expenditures per engineering student are: $540 for agricultural, $200 for chemical, $180 for civil, and $166 for electrical.
- Faculty salaries have improved, but not enough to remedy shortages.
- Since 1975, industry's R&D dollars to universities increased three-fold, making industry investment the fastest growing support of university research.

Section II: AEA Action 1981-1984 (pp. 29–49)

Assessment of AEA's impact on the shortage of EEs, CEs, CS professionals, and technicians is difficult. In some cases—such as the fellowship program to develop new faculty and passage of state and federal bills—the level of activity is known, but the full impact will not be seen for years. AEA's action program has gained it a reputation as an industry organization that is "making a difference."

Key actions taken:

- Set up an organizational infrastructure to undertake a program at both federal and state levels.
- Set a leadership goal for each company to spend 2 percent of its R&D expenditures on engineering education. Since 1982, $353 million has been "tracked" from member companies to engineering and CS programs—about 20 percent of what actually has been contributed.

- Provided leadership and information by: speaking to groups, legislative committees, and the media; managing a pilot job training program; and providing guidebooks for industry.
- Began Japan Research Fellowship Program to develop cadre of U.S. engineering graduate students who speak basic Japanese, have direct experience in Japanese research techniques, and a cultural sensitivity to Japanese business and trade. Begun with six students in 1984, the program will double in size in 1985.
- Established the Electronics Education Foundation in 1981 to stimulate flow of new monies from AEA companies directly to universities and initiated $7 million in corporate contributions through the Foundation to fund faculty development, recruitment, and retention.
- Initiated and continue to pursue long-range improvements through legislative/educational policy changes. AEA objectives in various stages of achievement are:

  Federal Level: Introduce the "High Technology Research and Scientific Education Act" to upgrade university scientific and engineering labs and encourage corporate research with universities; extend the IRS tax exclusion of employer-provided educational assistance; ensure that passage of the proposed Immigration Bill includes waivers for foreign students in math, science, and engineering from the two-year return-home requirement; and amend the NSF act of 1950 to ensure that basic scientific and fundamental engineering research are joint missions of the foundation.

  State Level:

  (1) California: Raise engineering faculty salaries at University of California (UC) campuses; create a statutory base for salary augmentation in "hard-to-hire" disciplines at California State University campuses and fund the augmentation; authorize the issuance of revenue bonds or negotiable notes for construction of research or educational facilities in high technology disciplines; pass tax incentives to encourage companies to donate equipment to higher educational institutions; secure state funds as a match for industry dollars for UC research projects; and improve vocational education at California Community Colleges.

  (2) Oregon: Establish and fund the Oregon High Technology Consortium to improve the quality of high technology postsecondary education, funded by state dollars on a matching basis with AEA company funds; improve engineering programs and enhance faculty salaries through new state allocation of dollars.

  (3) New Jersey: Gain agreement of the New Jersey Governor's Commission on Science and Technology to match AEA company dollars for fellowships and research equipment; support a state bond issue for the formation of four advanced technology centers and the upgrading of technical facilities at colleges across the state; and lay legislative groundwork for matching AEA-generated funds of $1.4 million beginning in 1985.

Section III—AEA Engineering & Technical Education Directions (pp. 51–59)

Due to shortages of faculty, facilities, and equipment, entry into engineering and CS programs by qualified students is still restricted, requiring AEA's continued focus. Therefore, future activities will focus on some aspect of present efforts, such as generating more CS fellowships, passing the federal R&D bill, and building into state faculty salary systems methods to minimize marketplace impact. New but related directions will also be taken, such as piloting one-day technical update courses for working engineers, offering noncredit videotapes from ACMEE universities to AEA members; getting an NSF match of industry dollars for fellowships, and generating industry funds to support the NSF Presidential Young Investigator program.

Table of Contents

Section I: Engineering Education 1984

1 A Changing Picture of EE/CE Shortfall

1 Need: To Separate Data on Electrical and Computer Engineers
2 Electrical Engineer Picture Brightens
3 Computer Engineer Picture Worsens
4 Defense Dollars Increase Engineer Demand
5 National "Agreement" on Demand/Graduate Supply Projections
6 Resolution of National "Disagreement" on the Shortfall

9 Improvements Insufficient to Offset Problems

9 Best and Brightest Continue to Seek Engineering Careers
10 Undergraduate Enrollments Continue Growing
10 Faculty Shortages—Still the Major Problem
13 Foreign Nationals Continue as Major Faculty Source
15 U.S. Students Still Avoid Graduate Study and Teaching
16 Effects of Faculty Shortages Continue
17 Faculty Growth Outpaced by Enrollments
19 Shortages impact Program Quality
19 Equipment Needs Still Unmet
20 EE/CE Instructional Equipment Needs Upgrading and Service
21 Engineering Faculty Salaries Improve
22 Private School Engineering Salaries Outpace Public
23 Decline of Salary Incentives to Pursue Graduate Study
25 Research Dollars to Universities Increase
27 AEA Needs to Continue to Improve Engineering Education

Section II: AEA Action 1981 - 1984

29 Organizational Infrastructure

29 Blue Ribbon Committee on Engineering Education
30 Engineering and Technical Education Committee
30 E-TEC Legislative Subcommittee
30 Regional/State Engineering Education (EE) Committees
31 State Legislative Education Subcommittees
31 Liaison with Other State Organizations
32 AEA Influence as Member of Educational Policy Groups

33 AEA's Leadership Role

34 Industry Goal: 2 Percent of R&D
35 Public Information Role
36 Model Programs

38 Establishment of a Data Base

38 Survey: Technical Employment Projections
39 "Matrices of Need" by Universities
39 Membership Survey: Continuing Technical Education Needs

39 Legislative Activities

39 Federal Legislation
41 State Legislation: Technical Education
46 State Legislation: Elementary and Secondary Education (K-12)

47 Electronics Education Foundation (EEF)

47 Fellowship-Loans to Develop New Faculty
48 Faculty Grants to Retain and Recruit Faculty
49 Equipment Purchases and Service Contracts
49 Miscellaneous Grants

51 Section III: AEA Engineering & Technical Education Directions

51 Computer Science
54 Continuing Technical Education
54 Job Projections Survey
55 Emerging Technology—Telecommunications
55 Japan Fellowship Program (Electronics Education Foundation)
56 Faculty Development Program (Electronics Education Foundation)
56 Federal Initiatives
58 State Initiatives

60 Glossary of Organizations and Terms

61 References

64 Addenda

Section I

Engineering Education 1984

A CHANGING PICTURE OF EE/CE SHORTFALL

Need: To Separate Data on Electrical and Computer Engineers

In a 1981 membership survey, AEA extrapolated job growth projections based on a survey of its member companies to the entire U.S. electronics industry in two fields—electrical engineering (EE) and computer engineering (CE). Juxtaposing these combined "demand" numbers against the projected supply of new EE and CE bachelor's degrees pointed to an annual shortfall through 1985 of upwards of 20,000. A second AEA survey in 1983 showed a similar five-year shortfall. Removing projections based on anticipated defense contracts which may not materialize reduces annual figures by 4,000 only.

A trend is now surfacing within both industry and academia which calls for distinguishing between EE and CE data. Member companies have increased interest in hiring graduates with computer engineering degrees. Though definitions vary, generally a computer engineer combines an electrical engineer's hardware design base with a specialty emphasis on software skills. The computer science (CS) professional lacks an EE or CE's hardware design base and specializes in software—as an analyst or a systems programmer.

Traditionally cross-overs occur between many fields when shortages require them. Typically, given software training, the electrical engineer can cross over and handle the computer engineer's tasks and, at some levels, those of the computer science professional. The computer engineer may cross over as an electrical engineer more easily than a computer science (CS) professional because of a stronger backgound in physical sciences. Whereas the computer engineer today commonly receives education within a university's School of Engineering, the computer science major may be found in mathematics, information sciences, or business administration as well as engineering. Decisions as to whether to offer a computer engineering degree and/or whether the computer science degree should be offered by the engineering school or another department vary from university to university. Differences of opinion are creating much debate.

Electrical Engineer Picture Brightens

Breaking AEA 1983 supply/demand projections out by EE and CE (Addenda C and D) and looking from a year's hindsight at the 1983 graduate supply, a changing picture emerges:

Electrical Engineers 1983

AEA Demand Projections	Projected BS/EE Degrees	Actual BS/EE Degrees	Projected Imbalance	Actual Imbalance
18,300 (includes defense)	13,200	14,900*	–5,100	–3,400
15,400 (excludes defense)	13,200	14,900*	–2,200	– 500

*20 percent more BS/EEs were actually graduated; however, only 80 percent typically enter industry employment.

Universities are graduating increasing numbers of electrical engineers in response to employer and student demand. In 1983, U.S. universities produced 18,590 BS/EE grads—the highest number in history. This is a 37 percent increase over 1980 and a 56 percent increase over 1970. (Addendum E)

BS/EE Degree Production

Year	BS/EE Degrees	Percentage of Change from Previous Year
1977	9,837	– 1.18
1978	10,702	+ 8.79
1979	12,213	+14.12
1980	13,594	+11.31
1981	14,558	+ 7.09
1982	16,094	+10.55
1983	18,590	+15.51

If this increased production continues, then it can be said that the electrical engineer supply-demand picture has improved and is moving toward balance. Improvements in quantity, however, may be offset by reductions in quality of educational programs—caused by faculty, equipment, and facilities shortages.

Computer Engineer Picture Worsens

The computer engineer picture appears to have worsened from that anticipated a year ago:

Computer Engineers 1983

AEA Demand Projections	Projected BS/CE Degrees	Actual BS/CE Degrees	Projected Imbalance	Actual Imbalance
18,100 (includes defense)	2,500	2,100*	–15,600	–16,000
15,200 (excludes defense)	2,500	2,100*	–12,700	–13,100

*20 percent more BS/CEs were actually graduated; however, only 80 percent typically enter industry employment.

Production of BS/CEs has risen dramatically from 139 degrees in 1970 to 2,643 in 1983—an 18-fold increase. Since 1977, however, BS/CE production has flattened out. An actual drop of 23 degrees occurred in 1983, the first time in four years:

BS/CE Degree Production

Year	BS/CE Degrees	Percentage of Change from Previous Year
1977	1,280	+60.80
1978	1,546	+20.78
1979	1,510	– 2.33
1980	1,816	+20.26
1981	2,356	+29.74
1982	2,666	+13.16
1983	2,643	– .86

The unanticipated drop may reflect the growing impact of computer engineering faculty shortages. Students cannot get courses they need to earn BS/CEs.

In total, the 1983 supply data suggest substantial improvement in electrical engineering numbers but some deterioration in computer engineering. It should be recognized, however, that the division into these categories is somewhat arbitrary and varies from school to school.

In both fields, industry demand remains consistently strong. Data above do not take into account new jobs in non-high-tech segments—banks, insurance companies, etc. Improvements in technology such as CAD/CAM, more efficient utilization of engineers, and some "in-mobility" from other fields are ameliorating but not solving imbalances.

Defense Dollars Increase Engineer Demand

One significant variable is the defense budget. A February 1983 National Science Foundation (NSF) study suggests increased defense spending may lead to a serious shortage of electronics/electrical engineers.[1]

Effects of Defense Budget on Demand for Engineers

	FY 32	FY 83	FY 84		FY 85	FY 86
	Actual	Estimated	Requested			
	In Billions of Dollars — Current					
Procurement	$64.5	$80.3	$94.0	(88.26)	$119.6	$136.4
R&D	20.1	22.8	29.6	(27.3)	32.6	34.1
Military Construction	4.9	4.5	5.8	(7.1)	9.9	10.3
	In Billions of 1972 Constant Dollars*					
Procurement	$28.96	$33.15	$36.96	(36.91)	$ 44.78	$ 48.64
R&D	8.71	9.41	11.64	(11.42)	12.21	12.16
Military Construction	2.12	1.86	2.28	(2.97)	3.71	3.67
	Estimated Total Engineers Required**					
Procurement	80,400	92,100	102,600	(102,500)	124,400	135,100
R&D	107,400	116,000	143,500	(140,800)	150,600	149,900
Military Construction	2,100	1,900	2,300	(2,900)	3,700	3,700
Total	189,900	210,000	248,400	(246,200)	278,700	288,700
Required Cumulative Incr. in Engrs. over '83			38,400	(36,200)	68,700	78,700
R&D Only			25,700	(24,800)	34,600	33,900

*5% inflation assumed 1982-1987, divide 1982 data by 2.31 to obtain 1972 constant dollars

**Based on (in 1972 constant dollars) $360,000 per year per engineer in procurement; $81,100 per year per engineer in R&D; $1,000,000 per year per engineer in construction ( ) = Senate-House Conference authorizations, Sept. 1983. Actual July 1983 CPI used for conversion to 1972 dollars.

Source: *Engineering Education*, December 1983, p. 159.

Depending on production of new weapons systems, tentative forecasts for defense budgets point to an annual increase in "defense-related engineering manpower ranging from five to seven percent . . . about 13,000 more . . . ."[2]

Gearing up engineer production to meet increased defense needs raises the spectre of layoffs when defense dollars decline—the "boom or bust" cycle. Yet even at the height of defense industry layoffs in 1971, engineering unemployment did not exceed 2.9 percent.[3] Negative publicity in the media kept the subject alive overly long and contributed to the 32 percent reduction in engineering enrollments which followed.[4] This marked the start of an unhealthy downslide of graduates.

The employment picture for engineers is consistently better than that for most other professions. The 1983 unemployment rate for engineers, for example, was only 2.5 percent compared to 9.5 percent for the total workforce.[5] The overall unemployment rate for engineers, including those laid off, increased by only .9 percent during 1983. James Briant Quinn of Dartmouth, writing in the *Sloan Management Review*, maintains that "even during the recession, there were 17,000 unfilled entry-level engineering jobs in the U.S."[6] Even in times of engineer shortages, NSF and Bureau of Labor Statistics (BLS) data suggest unemployment rates between .8 and 1.2 percent exist.[7]

National "Agreement" on Demand/Graduate Supply Projections

Much of the discussion by the media, some engineers, and some economists over whether a shortage of engineers exists is often attributable to mis-hearing industry's unmet need for electrical and computer engineers as an unmet need for *all* types of engineers. Data substantiate a strong and continuing demand for electrical and computer engineers and computer science professionals:

- NSF reports that while demand for chemical, mechanical, and civil engineers was "low" in 1983, it expects a 10 to 15 percent increase in demand for computer engineers, computer scientists, and electrical engineers and a "severe shortage of computer scientists."[8]
- BLS projects 48 percent engineering job growth between 1982-1995, with electrical engineering expected to grow fastest at 65 percent. It also predicts a shortfall by 1987 of computer professionals—systems analysts and programmers—ranging from 15 to 30 percent.[9]
- Engineering Manpower Commission (EMC) anticipates 1984 hiring activity for engineers will about double that in 1983.[10]
- The College Placement Council reports engineering graduates received 50 percent of all job offers made to the class of 1983, although they represent only five percent of the degree candidates.
- A 1983 AEA survey projects a five-year annual job increase of 10.6 percent for electrical engineers, 16.5 percent for computer engineers, and 15.2 percent for computer programmers/analysts.

Resolution of National "Disagreement" on the Shortfall

Representatives from AEA, BLS, NSF, and the Business-Higher Education Forum presented papers on engineer supply-demand at a National Research Council symposium in February 1984 in Washington. Data provided "did not reflect different supply and demand projections."[11] In fact, when one averages the high/low scenarios of NSF, close similarities appear:

Projected Demand for Engineers

Source of Projections	Demand
Bureau of Labor Statistics	45,000
National Science Foundation	46,000
American Electronics Association	48,000

Source: National Research Council (NRC) Symposium, Washington, D.C., February 1984.

The studies yield similar results for electrical engineers.

Economist Michael Mandel of Harvard University, comparing NSF, BLS, and AEA studies, says:

> It is clear that the gross demand projections of the three studies do not vary appreciably. The same statement holds for the supply projections for engineering graduates as well. When the AEA study compares its demand projections for electrical engineers (EE) to their supply projections, they find about one-third of new EE jobs cannot be filled by new EE graduates. The NSF study reaches the same conclusion—that without taking interoccupational mobility into account, one-third of new EE jobs cannot be filled by new EE graduates.[12]

Where NSF and AEA differ is on the question of how the graduate shortfall will and should be met. The NSF-sponsored model below concludes that people from other fields will "switch into electrical engineering." It "arrives at the conclusion that electrical engineering has sufficiently high in-mobility to ameliorate the shortage problem."[13]

Projected Labor-Market Balance in Engineering and Computer Specialty Occupations, 1987

(In thousands)

Occupation	New Entrants and Immigrants			New Entrants, Immigrants, and Occupational Mobility		
	Total supply	Balance surplus(+)/ shortage(–)	Balance surplus(+)/ supply	Total supply	Balance surplus(+)/ shortage(–)	Balance as percent of supply
Total engineers	1,598	84	6	1,437	14	1
Aeronautical/ astronautical	74	–35	–47	105	–4	–4
Chemical	88	27	31	64	3	5
Civil	218	29	13	190	1	1
Electrical/ electronics	390	–31	–8	421	1	0
Industrial	130	–1	–1	130	–1	–1
Mechanical	270	22	8	253	5	2
Metallurgical	23	5	22	19	1	5
Mining/petroleum	36	4	11	32	1	3
Engineers, n.e.c.	279	64	23	242	8	4
Computer specialists	466	–138	–30	593	–11	–2

Source: *Labor-Market Conditions for Engineers: Is There a Shortage?*, p. 50.

NSF Conclusion: Use people from other fields, and there is no shortage.

AEA, on the other hand, takes a somewhat different position. Some in-mobility will not only be necessary but is highly desirable. Today's electronics industry was in part created and continues to be strengthened by physicists and other scientists and mathematicians who bring to it healthy new insights and scientific perspectives. Electrical engineering in particular depends on physics, mathematics, and materials science "cross-overs." The question becomes how much in-mobility is desirable. The technological complexity of today's workplace increases the break-in time required for occupational cross-overs—raising costs, lowering productivity, and hindering competition in international markets. This makes in-mobility less a solution to technical professional shortages than a decade earlier.

AEA Conclusion: In spite of the availability of people from other fields, without more EE/CE and computer science graduates, the electronics industry will continue to be hampered by supply-demand imbalances.

In spite of asserting in-mobility as a solution, NSF's Jean Vanski places caveats on its ability to meet computer speciality job needs.

> It must be kept in mind . . . that personnel working on S/E [i.e. science and engineering] applications are generally expected to have a strong foundation in principles of physical sciences, mathematics, and engineering fields; for more complex applications, graduate degrees are becoming increasingly common. Therefore, if rapid growth occurs in S/E application systems analysis and programming, continued high transfer rates from other occupations may become increasingly more difficult to sustain . . . especially true, over time, as more advanced applications are introduced in areas such as CAD/CAM, information technology, telecommunications, and the sophisticated modeling encouraged by the development of the supercomputer.[14]

As she notes "real costs" of in-mobility and the potential that employee-hungry companies may pull graduate students and faculty from academia, Vanski appears to move philosophically to AEA's position:

> The larger the required adjustment [i.e. shortfall], the more likely it would be that employers would be forced to hire individuals with inappropriate training and/or experience. This . . . can impose real costs in terms of employer-supplied training, but more importantly in terms of lower labor productivity. . . . Finally, the costs of current market adjustments can have an impact on future labor supply . . . if the academic sector fails to retain necessary faculty or graduate students.[15]

IMPROVEMENTS INSUFFICIENT TO OFFSET PROBLEMS

Best and Brightest Continue to Seek Engineering Careers

Like three years ago, the problem is not a lack of qualified undergraduates. For the first time in recent years, more students chose engineering over business careers. An American Council on Education study of 250,000 freshmen entering college last fall found:[16]

Student Choice of Majors

Major Selected	Percentage of Students
Engineering	**11.7%**
Computer Science	**8.3%**
Business	**8.4%**
Of those selecting engineering, fields chosen were:	
Electrical	**4.3%**
Mechanical	**1.1%**
Industrial	**.5%**
Aeronautical	**1.2%**
Chemical	**.9%**
Civil	**.8%**
Other	**1.8%**

And for the first time since 1968, total law school enrollments dropped. Nationwide they totalled 127,195, down .5 percent from 1981-82; first year enrollments dropped three percent to 41,160.[17]

A recent NSF-sponsored survey of 760 college deans compared 1981-82 student quality with that five years earlier. "No Change" was reported by 61 percent, with 25 percent seeing "significant improvement," and 15 percent seeing a "significant decline."[18]

Noteworthy data in the survey are:

- 40 percent saw a shift of most able students into science and engineering, with 7 percent noting a shift away.
- 40 percent saw shifts within science and engineering: 32 percent to computer science, 18 percent to engineering, 6 percent to physical sciences.
- 60 percent saw no change in graduate student quality, with 10 percent noting improvement and 6 percent seeing a decline.
- Nearly 50 percent viewed foreign BS degree holders as equally qualified to U.S. students; of 50 percent who saw a difference, 43 percent thought U.S. graduates were better qualified.
- 66 percent saw no difference in Ph.D. recipients, although another 27.5 percent thought today's group better qualified.

Undergraduate Enrollments Continue Growing

Undergraduate engineering enrollment of 441,205 students (fall of 1983) is the highest in history, a 136 percent increase over 187,000 enrolled in 1973-74. In the last three years, undergraduate engineering enrollments have increased 11.0 percent, computer engineering 63.1 percent, and electrical engineering 31.8 percent:

Undergraduate Engineering Enrollments

Field	1980-81	1981-82	1982-83	1983-84	% of Change
All Engineering	**397,344**	**420,402**	**435,330**	**441,205**	**11.0%**
Electrical Engineering	**90,160**	**96,099**	**104,704**	**118,826**	**31.8%**
Computer Engineering	**14,914**	**18,319**	**24,261**	**24,321**	**63.1%**

Source: *Engineering Education*, October 1984, p. 46 and
Engineering Manpower Bulletin, No. 67, August 1983

These increases are unlikely to continue. Concerned that shortages of faculty, equipment, and space are having a negative impact on their programs, many colleges are capping or cutting back enrollments.

Admissions to UC Berkeley's College of Engineering reflect what is happening at top quality institutions. Berkeley received 2,637 or 3 1/2 times more applications than it had slots allocated—a 45 percent increase in applications over the year before, with no increase in student slots. Seventy-two percent or 1,900 of the applicants had a 3.5 GPA or better; 35 percent had 4.0 or better. (A new 5-point GPA system allows an extra point for an A in a high school honors course). Berkeley's Department of EE/CS received 1,481 or six times the applications it could accommodate. Seventy-five percent had 3.5 GPAs or better; 566 or 38 percent had a straight A average or better.

Although demographics may change this picture in the near future, poor high school math and science preparation or inadequate counseling of high school students do not rank as today's major problems.

Faculty Shortages—Still the Major Problem

The major problem continues to be a shortage of engineering faculty. Some improvements have been made in recruiting and retaining engineering faculty, with public schools having more difficulty than private. In 1980 the American Council on Education reported only 12 percent of engineering schools having a slight, moderate, or substantial increase in ability to recruit over 1979. This figure improved to 32.5 percent by 1982 and to 35.8 percent by 1983. On the other hand, in 1983, 26.7 percent still saw a decrease in their ability to recruit and retain faculty, down from 52.8 percent the prior year.

Change in Ability to Recruit and Retain Faculty, Fall 1983

Degree of Change	Public School		Private School		All Schools	
Substantial Increase	3.4%	(3.0)	1.8%	(10.3)	2.8%	(5.7)
Slight/Moderate Increase	32.8%	(22.2)	33.3%	(34.5)	33.0%	(26.8)
No Change	34.4%	(15.2)	43.8%	(13.8)	37.5%	(14.7)
Slight/Moderate Decrease	29.4%	(28.3)	21.1%	(25.9)	26.7%	(27.4)
Substantial Decrease	0	(31.3)	0	(15.5)	0	(25.4)
Total	100%	(100)	100%	(100)	100%	(100)

( ) 1982 survey results

Source: *Engineering Education*, October 1984, p. 52.

Overall, engineering faculty vacancies improved slightly—from a 10 percent vacancy rate for 18,000 full-time authorized teaching positions in 1980 to 8.5 percent in 1983 on a 18,440 base, up slightly from 7.9 percent in 1982.[19]

In electrical engineering, the vacancy rate improved between 1980 and 1982, and then worsened in 1983. The base of authorized full-time positions increased 13 percent between 1980 and 1983: More than half the vacancies had been unfilled one year or more.

Electrical Engineering Vacancies

Year	Full-time Authorized	Positions Vacant	Percentage Vacant
1980	3,570	333	9.3%
1981	3,900	331	8.5%
1982	3,780	291	7.7%
1983	4,040	390	9.7%

The computer engineering faculty vacancy rate was about the same in 1983 as it was in 1980, although authorized full-time positions have increased 63 percent and the number of CE vacancies has risen to 240.

Computer Engineering Vacancies

Year	Full-time Authorized	Positions Vacant	Percentage Vacant
1980	914	146	16.0%
1981	n.a.	n.a.	17.0%
1982	1,278	215	16.8%
1983	1,490	240	16.1%

In all engineering fields combined, some improvement in vacancies in all three ranks has occurred:

Engineering Vacancies by Rank

Year	Full Professor	Associate Professor	Assistant Professor
1981	3.4%	6.4%	24.4%
1982	2.9%	4.8%	20.8%
1983	3.6%	6.3%	20.0%

Specialized disciplines experienced higher vacancies in 1982 over 1981. Over 600 openings were reported by 140 schools in 1982 in hard-to-fill specialties such as microelectronics/VLSI design, electric power/power systems, robotics, CAD/CAM.

The major cause of the vacancy rate continues to be the inability to attract U.S. Ph.D. recipients to academia.

The concern that engineering faculty are leaving academia for industry jobs (i.e., outflow) is largely unfounded. Outflow was fairly balanced with those leaving industry to teach (i.e., influx) until 1983 when 197 more instructors entered academia than left it for industry jobs. Many believe that as the economy improves, increased net outflow to industry will occur.

Engineering Faculty Mobility

Year	Outflow	Influx	Faculty Gain/Loss
1981	266	261	−15
1982	227	255	+28
1983	300	497	+197

Foreign Nationals Continue as Major Faculty Source

Contrary to a commonly held opinion, the number of foreign nationals studying engineering has not increased significantly over the past four years. These foreign nationals study on visas requiring them to return home after graduation. While numbers are up slightly, percentage of the whole increased modestly for three years and last year declined at all engineering degree levels.

Foreign Nationals* Receiving Engineering Degrees

Year	Total Degrees Awarded	Degrees to Foreign Nationals*	% to Foreign Nationals*
Bachelor's Degrees			
1980	58,742	4,895	8.3%
1981	62,935	5,622	8.9%
1982	66,990	5,410	8.1%
1983	72,471	5,620	7.8%
Master's Degrees			
1980	16,941	4,402	26.0%
1981	17,643	4,589	26.0%
1982	18,289	5,216	28.6%
1983	19,673	4,915	25.0%
Doctoral Degrees			
1980	2,751	982	35.7%
1981	2,841	1,054	37.1%
1982	2,887	1,167	40.4%
1983	3,023	1,179	39.0%

*Does not include non-U.S. citizens who have permanent alien status.

While the number of undergraduate engineering foreign nationals has never been large, some realistic concern exists over the large number of foreign graduate students. The problem becomes greater if non-U.S. permanent resident degrees are added to those with temporary visas. According to NSF and the National Research Council:

> Since 1972, the number of engineering doctorates awarded non-U.S. citizens who are temporary residents doubled to over 1,000 while the number awarded to U.S. citizens declined by one-half to less than 1,200. In both 1981 and 1982, moreover, the number of engineering doctorates awarded to non-U.S. citizens—both temporary and permanent residents—exceeded the number awarded to U.S. citizens[20] [Addendum F].

These foreign nationals have not tended to displace U.S. citizens, since most U.S. citizens drop out by choice after the bachelor's degree. Until more U.S. citizens continue on to graduate study, foreign students provide tuition dollars needed by fiscally-fragile universities. They also serve as teaching assistants and continue to be the major source of new faculty.

Eighteen percent of all U.S. engineering faculty in fall 1982 were foreign-born—up from 17 percent the previous year.[21] The highest percentage was in computer engineering (20.7 percent) and the third highest in electrical engineering (19.2 percent). More than one-fourth (26 percent) of all assistant engineering professors did not receive BS degrees from a U.S. university.[22]

President Sam Hulbert of Rose-Hulman Institute of Technology says that half to three-quarters of all his engineering faculty job applicants are foreign. At Rose-Hulman, three new EE faculty have been hired since 1980. All are foreign-born.[23] In the California State University system, a 1983 AEA survey found 49 percent of new tenure-track engineering faculty hired between 1980 and 1983 graduated from non-U.S. high schools or colleges and 56 percent of electrical and computer engineering new hires were foreign.

Numbers and percentages of master's and doctoral EE and CE degrees showed somewhat steady increases of foreign nationals between 1980 and 1982. Last year percentages as a whole dropped at all engineering degree levels as well as for electrical and computer engineering.

Engineering Degrees Awarded to Foreign Nationals* and U.S. Citizens

Year	Total Degrees	Degrees to Foreign Nationals*	% to Foreign Nationals*	Degrees to U.S. Citizens	% to U.S. Citizens
Electrical Engineering					
Master's Degrees					
1980	3,660	862	23.6%	2,798	76.4%
1981	3,762	875	23.3%	2,887	76.7%
1982	4,186	1,097	26.2%	3,089	73.8%
1983	4,645	1,125	24.2%	3,520	75.8%
Doctoral Degrees					
1980	523	171	32.7%	352	67.3%
1981	503	181	36.0%	322	64.6%
1982	549	229	41.7%	320	58.3%
1983	628	225	35.8%	403	64.2%
Computer Engineering					
Master's Degrees					
1980	1,254	259	20.7%	995	79.3%
1981	1,295	322	24.8%	973	75.2%
1982	1,365	310	22.7%	1,055	77.3%
1983	1,419	235	16.6%	1,184	83.4%
Doctoral Degrees					
1980	159	58	36.5%	101	63.5%
1981	171	50	29.2%	121	70.8%
1982	129	57	44.2%	72	55.8%
1983	102	25	24.5%	77	75.5%

*Does not include non-U.S. citizens who have permanent alien status.

Decreased doctoral enrollments of foreign nationals are balanced by increases in U.S. citizen enrollments. Hopefully this heralds a reversal of the earlier trend.

U.S. Students Still Avoid Graduate Study and Teaching

In a study comparing the 1982 Tau Beta Pi engineering honor society class with that of 1977, "a profound lack of interest in teaching" and "little interest in full-time engineering graduate study" was found.

- 28 percent in 1982 preferred industry salaries to graduate study—up from 5 percent in 1977.
- 25 percent in 1982 wanted to work and pursue a master's degree part-time—up from 7 percent in 1977.
- 7 percent (58 students) selected engineering teaching careers; 2 percent or 14 of the 1977 class who became engineering professors are still teaching.[24]

Not only the "best and brightest" avoid faculty careers. The proportion of all engineering Ph.Ds who elect not to teach is increasing. An NRC study of 1981-82 engineering and computer science Ph.D. recipients found only 21 percent of EE graduates were going to teach compared to 33 percent three years earlier; 25 percent of the CS graduates were going to teach.

While the EE/Ph.D. pool increased 125—or 25 percent—since 1981, the CE/Ph.D. pool dropped by an alarming 69—or 40 percent—over the same period.

Applying the 21-percent-choose-to-teach formula to the 628 new EE/Ph.Ds and subtracting 148 (2/3 of the 225 foreign nationals likely to return home), leaves 100 new EE professors to fill the 390 authorized vacancies. Applying the 25-percent-choose-to-teach formula to the 102 new CE/Ph.Ds, and subtracting 17 (2/3 of the 25 foreign nationals likely to return home), leaves eight new CE professors to fill the 240 authorized vacancies. While these data are startling enough, two other aspects of the picture point towards an increasingly difficult quick-fix.

One is that an additional 5 percent new faculty are needed each year to replace those who die, retire, or leave teaching.[25] A 1982 AAES/ASEE report says 22 percent of U.S. engineering faculty can be expected to retire within the next 10 years. Data from several states corroborate the national figures. AEA's 1983 survey of the California State University System, for example, found 8 percent of its engineering faculty retired between 1980 and 1983; another 11 percent are expected to retire by 1986.

The second is that the vacancy rate for authorized positions is likely understated. Ed Lear, Executive Director of ASEE says, "Administrators will not authorize positions, even if they are needed if there is no prospect of their being filled." Deans from 186 engineering schools reported in 1983 their authorized full-time faculty strength was only 85 percent of what was needed. This translates into nearly 22,000 full-time engineering faculty needed and a faculty shortage more likely 23 percent than the 8.5 percent shortfall reported on currently authorized positions.[26]

Effects of Faculty Shortages Continue

Inability to recruit and retain faculty is still affecting engineering departments' ability to conduct research and provide quality education, although some improvements have occurred. The 1983 Engineering College Faculty Shortage Project (ECFSP) found the matter more serious at public than at private schools:

Effect of Inability to Recruit and Retain Faculty, Fall 1983

Effect	Public School		Private School		All Schools	
Reduction in Research	28.6%	(47.6)	16.7%	(29.6)	25.5%	(42.2)
Increased Teaching Loads	77.1%	(80.9)	75.0%	(63.0)	76.6%	(75.6)
Greater Reliance on Teaching Ass'ts. and/or Part-time Faculty	97.1%	(80.9)	58.3%	(55.6)	87.2%	(73.3)
Courses Not Offered	45.7%	(58.7)	41.7%	(44.4)	44.7%	(54.4)
No Significant Effect	2.9%	(6.3)	25.0%	(3.7)	8.5%	(5.6)

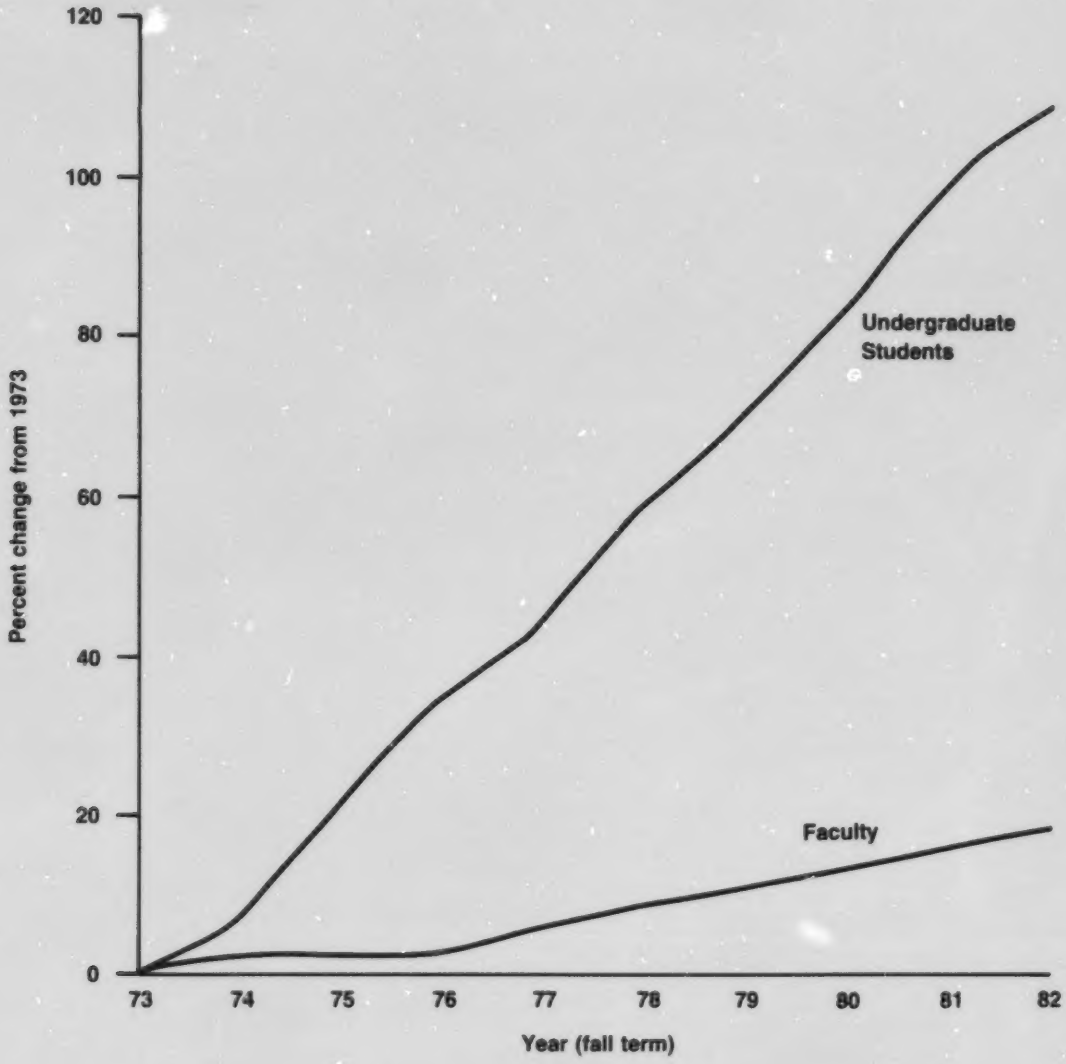
( ) 1982 survey results

Source: *Engineering Education*, October 1984, p. 52.

Faculty Growth Outpaced by Enrollments

Modest faculty growth coupled with heavy student enrollment increases have turned a serious situation to a dire one. Engineering enrollments increased 100 percent between 1972 and 1982, but faculty numbers increased only 10 percent.

Growth in Engineering Enrollments and Faculty 1973-1982



From: W. Edward Lear, ASEE

A National Association of State Universities and Land Grant Colleges (NASULGC) study of 29 public engineering universities found a 32 percent increase in student-to-faculty ratio over five years:

NASULGC Study of Student-Faculty Ratios

Year	No. of Undergraduates Per Faculty Member	No. of Undergraduate and Graduate Students Per Faculty Member
1975-76	6.9	9.9
1980-81	9.8	13.1

Accreditation Board for Engineering and Technology (ABET) data for 1982-83 show electrical engineering as having the second highest student-to-faculty ratio of all engineering fields surveyed:

ABET Study of Student-Faculty Ratios

Field of Engineering	Students Per Faculty Member
Aeronautical	30.3
Electrical	27.8
Chemical	25.0
Civil	19.3
Agricultural	11.4

Average enrollment in senior level professional/design courses and labs increased by 56 percent between 1977 and 1982.

Change in Size of Section Enrollments, 1977 and 1982

	"Typical Case" Class Size				"Worst Case" Class Size			
	1977		1982		1977		1982	
	Average	High	Average	High	Average	High	Average	High
Senior Level Professional	23	50	36	185	37	154	64	187
Senior Level Design	22	53	32	80	32	120	49	151
Senior Level Project	16	100	23	120	23	100	33	120
Junior/Senior Laboratory	17	70	24	100	24	121	36	205

Source: *Engineering Education*, October 1983, p. 53.

The NASULGC study found that to restore the student-to-faculty ratio to the 12-to-1 rate of 1975-76 and adjusting it for faculty research commitments, 6,000 to 7,000 more engineering faculty would be required.[27]

Shortages Impact Program Quality

ABET considers five areas when evaluating undergraduate programs: faculty, curriculum, facilities, administrative support, and institutional support. In 1978 almost 60 percent of those engineering programs examined by ABET received a full six-year accreditation. By 1983, the proportion receiving full accreditation had declined to 35 percent (Addendum G). For programs examined in 1982-83, many problems were in faculty and curriculum areas. Eighty-five percent of the programs losing their accreditation or receiving a "show cause" why accreditation should not be terminated had curricular problems; 65 percent had "faculty criteria deviations." The loss in undergraduate educational quality over the last five years can be inferred from changes in ABET accreditation results; they are a direct measure, through on-site inspections, of the quality of the programs offered.

ABET Results

Evaluation Results	1978 (280 Programs)	1983 (353 Programs)
Received full 6-year accreditation	58%	34.5%
Received only 3-year accreditation	14%	34.5%
Were not accredited	5%	9%
Had to show cause why accreditation should not be terminated	7%	8%
Received 3-year accreditation but had to report in interim	16%	14%
	100%	100%

The effects of faculty shortages are daily in evidence to students who experience frustration in not getting courses, inadequate academic advising, etc. They observe stresses their professors tolerate due to large class sizes. The lack of instructional equipment simply reinforces students' views of academic careers as unattractive.

Equipment Needs Still Unmet

Universities continue to report outdated and unusable instructional and research equipment in engineering and computer science. In 1982, 87 of 240 programs examined by ABET had "unsatisfactory" instructional labs. Of the remaining 153 programs, 57 labs were rated "satisfactory," with only eight of the 240 getting an "excellent" or "outstanding" rating.

A 1984 NSF study of existing engineering and scientific research equipment costing from $10,000 to $1 million reports that university researchers classified about "one-fourth of the items in their 1982 research equipment inventory as obsolete and no longer in research use." The situation was more severe for engineering and physical science, which had 24 percent obsolete equipment compared to computer sciences with 17 percent obsolete equipment. Only 16 percent of all academic research equipment in 1982 was characterized as "state-of-the-art."[28]

Half the department chairmen reported existing equipment as "insufficient." Ninety percent said equipment shortages inhibited critical research. Thirty-one percent of the research equipment was over 10 years old; 20 percent was 6-10 years of age. Two-thirds of the equipment was acquired partly or entirely with federal dollars.[29] Current estimates to update lab equipment in all 286 engineering colleges range from $1 to $2.5 billion.[30]

Research equipment in academia is twice as old as that in industrial and government labs.[31] Stanford's Dean of Engineering Jim Gibbons says they select research "partially in terms of the equipment we have, or can easily build, or buy for a moderate amount."[32]

EE/CE Instructional Equipment Needs Upgrading and Service

Decreased academic capital outlay budgets for costly state-of-the-art EE/CE instructional equipment and lack of funds for service and repair contribute to keeping EE/CE instructional labs at less than optimal operational levels.

In a 1984 AEA survey of EE department heads, 39 percent of the respondents indicated they have instructional equipment currently not usable and 31 percent turned down offers of equipment donations because they lack service and repair monies. Twenty-nine EE/CE departments will spend almost $900,000 to service and repair their instructional equipment for 1984-85. If these programs are representative of the 290 ABET-accredited departments, almost $9 million will need to be budgeted this year alone for EE/CE equipment service and repair. And respondents indicated they needed on average an additional $21,000 over the budgeted amount. If these departments are representative of the whole, an additional $6 million is needed to make all EE/CE equipment usable for an entire academic year.

Antiquated research facilities result in lost research dollars. Experts estimate rebuilding at about $1.3 billion per year. Even today's state-of-the-art lab may last for only 10 years. And few have been built since the early 1960s. Those built then may not meet safety regulations and lack basic repairs to ensure successful operation of expensive equipment.[33]

ABET data rated EE programs second to the bottom compared to all engineering fields in terms of capital expenditures per student. EE programs surveyed spent an average of only $166 for capital expenditures per student, compared to $540 in agricultural engineering, $200 in chemical engineering, and $180 in civil engineering.

Engineering Faculty Salaries Improve

Recruitment and retention problems have caused most universities over the last three years to raise engineering faculty salaries over and above university-wide adjustments. A fall 1982 AAES/ASEE Engineering Deans Survey showed 85 percent reporting such increases at the assistant professor rank and 75 percent for associate and full professors.

Although the data below are from a variety of sources, comparisons show trends of improvement:

Engineering Faculty Salaries - Average Nine Months

Rank	Year	High	Average	Low
Assistant	1980-1981	n.a.	$21,758	n.a.
	1981-1982	$35,860	$24,100	$12,720
	1982-1983	$46,610	$26,400	$16,930
	1983-1984	n.a.	$27,697	n.a.
Associate	1980-1981	n.a.	$25,793	n.a.
	1981-1982	$45,350	$28,100	$16,000
	1982-1983	$48,500	$30,180	$17,550
	1983-1984	n.a.	$31,920	n.a.
Professor	1980-1981	n.a.	$33,295	n.a.
	1981-1982	$64,700	$35,300	$20,000
	1982-1983	$70,700	$37,800	$21,150
	1983-1984	n.a.	$40,929	n.a.

Sources: 1980-81 and 1981-82—AAES/ASEE Surveys
1982-83—ECFSP, November 1983
1983-84—John Minter Associates

Average gains have been 27 percent for assistant professors, 24 percent for associate, and 23 percent for full. 1983-84 engineering faculty salaries were seven to eight percent higher than the year before, a greater increase than that for any other discipline reported. Appropriately, greater increases occurred for assistant professors, who have less opportunity to augment dollars through consultancies, summer teaching, and research than do associate and full professors.

Two standard faculty income sources assist to bridge industrial and academic salaries—summer teaching and consulting.

Forty-four percent of faculty in all disciplines combined teach one or more summer courses. Average total compensation is $3,546. Engineering professors appear to earn more:[34]

Summer Teaching for Engineering Faculty

Rank	% Teaching in Summer	Average Compensation
Assistant	29%	$5,029
Associate	33%	$4,638
Full	40%	$5,494

Few national data exist on faculty consulting income. A 1980 study by John Minter Associates found engineering faculty consulting incomes at research universities averaging $6,000.[35] Generally, neither consulting nor summer teaching offsets the 33 percent differential between industry and education salaries.

Private School Engineering Salaries Outpace Public

1983-84 salaries in selected disciplines for all assistant and new assistant professor ranks were higher at public schools than private—except for engineering:

Average Nine Month Faculty Salaries Selected Fields 1983-84

Field	Assistant Professor		New Assistant Professor	
	Public	Private	Public	Private
Accounting	$26,158	$25,193	$26,862	$23,692
Business Management	25,912	25,265	26,558	26,063
Computer & Info. Science	26,042	24,342	25,549	23,161
Education	22,258	20,885	21,255	19,534
Mathematics	23,144	21,427	22,549	20,635
Physics	22,846	22,348	21,659	20,998
Sociology	21,740	20,366	20,371	20,137
Letters	21,875	19,022	19,634	19,002
Chemistry	21,683	20,627	20,669	19,394
Engineering	25,439	28,438	25,743	28,662

Source: College and University Personnel Association

Engineering faculty shortages continue to be more severe at public institutions than private, partially because private pay more.

Engineering Faculty Vacancy Rates

Field	Public			Private		
	1981	1982	1983	1981	1982	1983
All Engineering	9.5%	8.4%	9.5%	7.9%	6.6%	5.4%
Electrical Engineering	8.8%	8.3%	11.0%	7.9%	6.3%	6.0%
Computer Science/Engineering	17.0%	17.9%	19.2%	16.8%	14.7%	8.3%

Source: ECFSP/ASEE

Decline of Salary Incentives to Pursue Graduate Study

The improvements in engineering faculty salaries are still insufficient to encourage U.S. citizens to pursue academic careers. Since 1981 industry salary incentives for graduate degree holders appear to have increased each year nationally and in AEA companies. However, the differences between graduate and undergraduate starting salaries declined slightly last year.

Median Engineer Salaries Upon Graduation

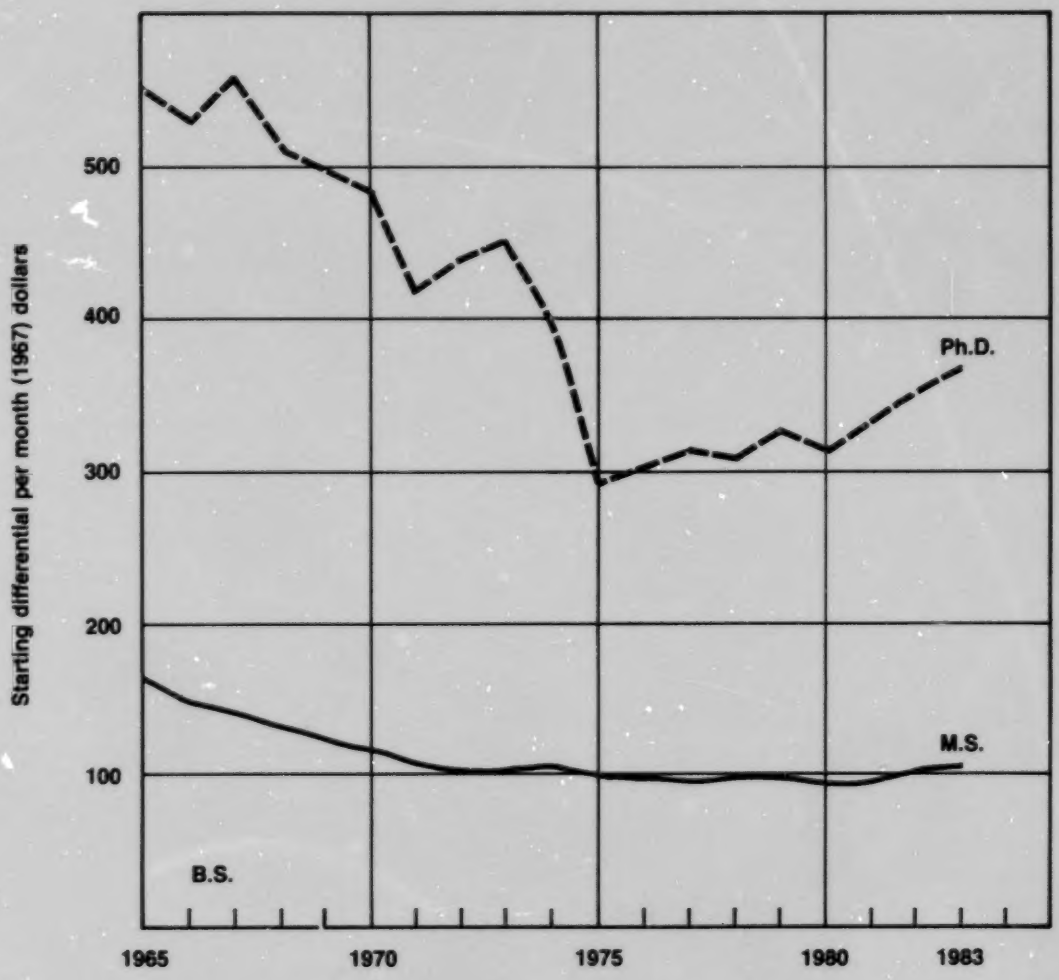
	1981-82	1982-83	1983-84
Engineering Manpower Commission Data			
B.S.	$22,000	$24,000	$24,400
M.S.	$25,500	$28,000	$30,000
B.S. - M.S. Differential	$ 3,500 or 15.9%	$ 4,000 or 16.6%	$ 5,600 or 22.9%
Ph.D.	$33,000	$36,800	$37,200
B.S. - Ph.D. Differential	$11,000 or 50.0%	$12,800 or 53.3%	$12,800 or 52.5%
AEA Data*			
B.S.	$22,236	$24,246	$24,954
M.S.	$26,994	$29,627	$30,160
B.S. - M.S. Differential	$ 4,758 or 21.3%	$ 5,381 or 22.1%	$ 5,206 or 20.8%
Ph.D.	$34,586	$38,915	$40,433
B.S. - Ph.D. Differential	$12,350 or 55.5%	$14,669 or 60.5%	$15,479 or 62.0%

*Includes electrical, computer, mechanical engineers but excludes industrial or manufacturing.

Source: *AAES Engineering Manpower Bulletins* 1981, 1982, 1983 and AEA *Salary Surveys of Professional Engineers*, 1982, 1983, 1984.

Salary incentives for master's and doctoral degrees when viewed using 1967 constant dollars also show a decline in differential since 1965. For example, master's degree differentials declined from $150 a month in 1965 to a low of $90 in 1980, back up slightly to $110 a month in 1983. Doctoral degree differentials declined from $550 a month in 1965 to a low of $310 in 1980, up some to $360 in 1983. More increases will be needed to encourage U.S. citizens to pursue graduate degrees.

Constant (1967) Dollar Difference in Monthly Starting Salaries Between Ph.D., M.S., and B.S. Holders in Electrical Engineering



Source: *Engineering Education*, December 1983, p. 161.

Research Dollars to Universities Increase

In 1984, $97 billion is expected to be invested in R&D in the U.S. This represents an 11 percent (6 percent in real terms) increase over 1983. Nationally, R&D dollars have more than doubled—from $35 billion in 1975 to $72 billion in 1981—although inflation adjusts the increase to one-third.

Federal dollars accounted for about 46 percent of all 1981 and 1982 R&D monies. Federal dollars for 1983 were to increase 9 percent (4 percent in constant dollars) to $40.3 billion and in 1984 by 10 percent (5 percent in constant dollars) to $44.3 billion. The U.S. Office of Management and Budget estimates R&D will rise 14 percent to $51.8 billion in the 1985 federal budget.

Defense is a major part of federal R&D dollars.[36] Military programs will likely claim $36 billion or almost 70 percent of the 1985 total.[37] Overall, R&D federal dollars "continue to support two-thirds of the nation's basic research. . . . One-half of this support is devoted to the nation's universities and colleges."[38]

Industry's R&D dollars to universities have historically been small compared to the total university R&D picture—3 percent in 1975, 2.8 percent in 1979, and only 2.2 percent in 1982. Yet since 1975, industry's R&D dollars to universities increased almost three-fold—from $112,952,000 to $325,594,000. This makes industry R&D the fastest growing segment in university research. The federal R&D tax credit has been one of the driving forces of this growth (See page 39).

R&D Expenditures at Universities and Colleges: Fiscal Years 1975-82

(Dollars in Thousands)

Source and Character	1975	1976	1977	1978	1979	1980	1981	1982
Total	3,408,691	3,729,007	4,066,953	4,624,673	5,361,408	6,080,118	6,818,343	7,260,637
Source of Funds:								
Federal Government	2,288,070	2,511,867	2,726,126	3,058,734	3,595,271	4,093,586	4,559,049	4,749,264
State and Local Governments	331,646	363,746	373,943	414,389	470,073	493,649	540,050	585,559
Industry	112,952	123,145	138,807	169,623	192,753	235,522	287,550	325,594
Institutional Funds	417,425	445,590	514,275	622,646	729,731	828,774	983,445	1,097,602
All Other Sources	258,598	284,659	313,802	359,281	373,580	408,587	448,249	502,618
Character of Work:								
Basic Research	2,409,777	2,548,820	2,799,649	n.a.	3,612,278	4,026,180	4,576,230	4,850,953
Applied Research and Development	998,914	1,180,187	1,267,304	n.a.	1,749,130	2,033,938	2,242,113	2,409,684

Source: *National Patterns of Science and Technology Resources 1984*, NSF(84-311), p. 61

In-house company research benefits individual companies' economic success. Basic research conducted at universities, however, achieves two broader "societal" goals. First, it results in the transfer of new knowledge throughout the economy, benefiting many companies. Second, it helps retain and attract quality engineering faculty and graduate students who wish to conduct research as well as teach.

Increased R&D dollars have been flowing to U.S. universities over the last few years. It is expected that $3.2 million or 60.5 percent more dollars will be spent at universities in 1984 than were spent in 1979; in constant dollars this represents a 15 percent increase. As a percentage of all R&D in the U.S., however, one percent less will be conducted at universities in 1984 (8.8 percent) than in 1979 (9.8 percent) (Addendum H).

Appropriately, the majority of R&D dollars to universities go to those granting doctorates—97 percent in 1975 and 97.8 percent in 1982. Yet some 25 percent of U.S. engineering colleges do not grant doctorate degrees. Their faculties also need research monies not only to augment salaries but to enrich academic lives and ensure excellence of the teaching base.

Several academic leaders point with concern at the concentration of outside dollars which often bypass "schools that are putting out most of the engineers." Bob Page, former Dean of Engineering at Texas A&M and chairman of the National Engineering Deans Council, says, "There are pretty strong signals that unless something is done to distribute money to more schools, we're going to end up with only 25 engineering schools in the country with quality education."[39] On the other hand, those like Don Glower, Dean of Engineering at Ohio State University disagree, saying, "The most efficient way to improve engineering education is to improve the strong schools."[40]

Given these differing views, companies may be best advised to take stock not just of colleges from which they "recruit" but also of schools from which their successful new hires graduate. This may change distribution of company equipment donations, consultancies, etc., to more equitably support the institutions which in reality underpin a company's employee base. Company fellowship monies to support U.S. citizens who wish to get Ph.Ds and teach, on the other hand, are best placed in well-known, quality research institutions to ensure that top students become engineering faculty members.

AEA Needs to Continue to Improve Engineering Education

The 1983 ECFSP survey documents improvements in engineering faculty recruitment and retention:

Factors to Which Improvement in Ability to Recruit and Retain Faculty Were Attributed, Fall 1983

	Public Schools	Private Schools	All Schools
More Attractive Salaries from Regular University Resources	67.4%	85.0%	73.0%
Industry-Sponsored Programs for Enhancing Salaries	25.6	30.0	27.0
State Government Activities to Improve Funding for Engineering	20.9	5.0	15.9
Improved Faculty Environment Other than Salary	39.5	35.0	38.1
Other	23.3	25.0	23.8

Source: *Engineering Education*, October 1984, p. 52

The ability of U.S. electronics and information technology companies to remain economically competitive is predicated on readily finding quality educated engineers and technical professionals. Sufficient faculty are a proven key to both quantity of graduates and quality of their education. AEA's national effort to improve U.S. engineering education, when compared against the factors found to improve faculty recruitment and retention, continues to be "on the mark."

Section II

AEA Action 1981-1984

In June 1981 AEA began to redress the shortage of technical people. It focused activities on electrical and computer engineers, computer science professionals, and electronic technicians.

Assessment of AEA's total impact is impossible. One major goal, for example, is to bring the problem of an inadequate supply of technical people to the awareness of industry, education, and government. While many new company contributions programs and unprecedented industry involvement in educational legislative issues have occurred since AEA began its efforts, it is inappropriate to take more than a small share of credit.

Today, however, as in 1981, most national groups and associations confine themselves to discussing the problem and issuing reports. AEA continues its action program and is increasingly focusing on faculty shortages. For this reason, it has gained presence as an industry organization which is "making a difference."

The following catalogs major Association activities since 1981. In some cases—such as the almost $7 million raised by companies through AEA's Foundation for fellowships and faculty grants—the level of activity is known, but the full impact will not be seen for years. In others, results are difficult to measure because their full value is in the "ripple effect" on the actions of others.

ORGANIZATIONAL INFRASTRUCTURE

Blue Ribbon Committee on Engineering Education

This committee of select industry and education chief executives (Addendum A) was appointed by AEA's Board of Directors to study the problem and develop a plan for Association action. Chaired by Dr. William Perry, former U.S. Undersecretary for Research and Engineering, the committee guided the program start-up. In 1982 it assumed the role of National Advisory Committee to AEA's new Electronics Education Foundation.

Engineering and Technical Education Committee

In 1982 the AEA Board authorized formation of a national Engineering Education Committee (Addendum B). Its purpose is:

> To recommend to the AEA Board of Directors program directions and the allocation of resources necessary to undertake unique activities and services with industry, educational institutions, and state and federal government bodies which assure the availability of qualified technical people to meet company needs. Between Board meetings, as an extension of the Board, the committee makes policy interpretation decisions of a time-sensitive nature.

In 1983 the AEA Board approved changing the name to *Engineering and Technical Education Committee* (E-TEC) to reflect the broader scope of technician issues, importance of continuing technical education activities, and future involvement in pre-college math and science education.

E-TEC Legislative Subcommittee

In 1983 a legislative subcommittee was organized to address federal educational legislative issues. Its purpose is:

> To provide legislative direction to AEA staff in implementing AEA Board-approved initiatives; within guidelines set by E-TEC and the Board, determine positions on bills initiated by others related to AEA priorities; assist desired outcomes through lobbying and/or testifying before committees; and coordinate with other AEA committees concerned with legislation (Addendum B).

Regional/State Engineering Education (EE) Committees

Since 1982 committees of industry executives have been organized in 13 AEA Councils: Washington, Oregon, San Francisco, Santa Barbara, Orange County, San Diego, Colorado, Texas, Massachusetts, New Jersey, New York, Los Angeles, and Minnesota (Addendum I). Organizing now or in the near future are: Arizona, Connecticut, and Florida. Generally, these groups of five to ten high-level executives review the needs of their local engineering colleges and universities. They then devise and implement plans to address them that typically consist of fundraising and/or legislative lobbying.

Over 140 industry executives have participated actively in EE committees over the past two years. They have been instrumental in achieving state and federal legislative success and in raising almost $7 million through AEA's Foundation for fellowships, grants, and equipment.

State Legislative Education Subcommittees

Within the framework of national AEA priorities for postsecondary technical education, Oregon and California have active subcommittees to deal with such matters under their AEA State Government Affairs Committees. Members are either government affairs managers or CEO-level executives of AEA companies. They provide input and assistance to staff in educational policy matters or state legislative issues. Gary Burke, Manager, Community and Government Relations, IBM, chairs the California Subcommittee; Gary Conkling, Manager, Government Relations, Tektronix Inc., is chair in Oregon.

Liaison With Other State Organizations

In some states existing organizations have long-established or newly developed educational legislative capability and interest. Where their memberships consist of many AEA companies, the Association attempts to establish a close working relationship with the groups. Two separate organizations which take the same position on issues before a state legislature strengthen the industry position of both. Cooperation with other organizations takes many forms in addition to legislative lobbying.

Massachusetts High Technology Council (MHTC)

Early in 1982 MHTC publicly adopted AEA's goal of each company giving 2 percent of its R&D to engineering education. It co-sponsored with AEA and provided the major staff work for a statewide Massachusetts conference on engineering education issues.

In 1983 AEA's national technical employment projections survey took on a special emphasis in Massachusetts with MHTC not only giving helpful input into the questionnaire but assisting in generating company responses. AEA provided a special data breakout for the state, and MHTC undertook special publicity of results.

MHTC joined with AEA to raise over $1.3 million for fellowships and faculty grants from companies to universities through AEA's Foundation. Several MHTC executives who did major fundraising were not AEA members.

Others

The Minnesota High Technology Council (MHTC) shares many common members with AEA and upon occasion sponsors joint programs. Like its Massachusetts counterpart, it jointly participated in AEA's national job projections survey.

The Colorado Association for Commerce and Industry (CACI) shares members with AEA and is a source of assistance on educational legislative matters through its Higher Education Council. The newly formed Washington Council For Technology Advancement (WCTA) also shares membership and potential in joint legislative activities related to higher education. New York's Long Island Forum for Technology plans to jointly sponsor a High Technology Day with AEA the early part of 1985 to focus industry's, legislators', and the Governor's attention toward improving the state's engineering education.

AEA Influence as Member of Educational Policy Groups

While legislative remedies are often necessary to improve education, longterm change in many cases comes about from within educational policy bodies—Boards of Regents, Trustees, etc. Increasingly, electronics industry executives are being appointed to these higher education groups. Robert Noyce of Intel Corporation and Dean Watkins of Watkins-Johnson Company, as members of the University of California Board of Regents, Ray Stata of Analog Devices as a former member of the Massachusetts Board of Regents, and others bring a much-needed industry perspective to groups long dominated by labor and non-electronics.

When an executive is appointed to represent AEA as well as an individual company, the individual leverage increases. The executive can work back through the Association to other companies for input. This brings a larger support base, and compounds effectiveness at the board level. Examples of new AEA positions follow.

Board of Governors, California Community Colleges

Since 1982, the AEA Vice President for Engineering and Technical Education has held a Governor appointment to the 15-member state board which sets policy and distributes state funds to 106 California community colleges. AEA perspectives were instrumental in forming a Vocational Education Committee to this Board. It has since adopted policies for improving voc ed in eight key areas: planning and coordinating voc ed programs; allocation and use of voc ed funds; access to voc ed programs and meeting student needs; assessment, guidance, and voc ed counseling; linkages with the private sector and meeting employer needs; staffing and personnel standards for faculty and administrators; evaluation and accountability; and dissemination of information on students and programs. Through the Board, key community college voc ed reform legislation important to industry interests is moving toward enactment.

Keep America Working Task Force

Phil Hammond, a member of AEA's E-TEC and AEA's national Board of Directors, and Chairman and CEO of Dynamic Sciences, represents AEA on the national task force "Keep America Working." Co-sponsored by the American Association of Community and Junior Colleges and the Association of Community College Trustees, industry, education, and labor members identify models of public and private partnerships with community colleges to foster duplication. Their primary aim is to promote ways U.S. community colleges can play an increasingly important role in economic development.

IEEE Task Forces

The AEA Vice President of Government Affairs serves as a member of IEEE's Technical Information Committee. AEA Senior Manager for Engineering and Technical Education serves as a member of IEEE's Education Society Advisory Committee. AEA representatives will serve as members of IEEE committees organized under the National Research Council to develop a National Engineering Research Agenda. These relationships with the largest professional society of electronics engineers assist in strengthening communications between AEA company executives and engineering professionals.

Institute for Innovative and Applied Technology

Glenn Penisten, Chairman of AEA's E-TEC, past Chairman of AEA, and Chairman of AMI/Gould, Inc., along with the AEA Vice President for Engineering and Technical Education serve on the board of the nonprofit Institute for Innovative and Applied Technology (IIAT). Begun in 1983 at San Francisco State University, IIAT represents a pilot effort to develop a model to bring industry research and product development contracts into a university not historically experienced as a research institution. The intended outcome is to assist engineering faculty retention and recruitment.

EDUCOM

The AEA Vice President for Engineering and Technical Education serves as a Member of the Board of Trustees of EDUCOM. A nonprofit organization headquartered at Princeton, EDUCOM offers special services to bring telecommunications technology into higher education to improve productivity and efficiency. It provides intercampus electronic mail networks between 37 higher education institutions, government organizations, and industrial research laboratories. It also offers seminars to help colleges and universities develop new computer literacy programs and improve existing ones.

AEA'S LEADERSHIP ROLE

Recognizing that engineering and technical education problems need the attention of many groups, AEA has sought to play a leadership role in stimulating others. By setting goals for "investing," offering guidebooks on how to initiate industry-education partnerships, engaging in pilot programs to develop replicable models, etc., AEA has made a significant "ripple effect" impact.

Industry Goal: 2 Percent of R&D

Dollars to engineering education are an investment in economic strength for electronics and information technology companies. In 1981 the AEA Board set a leadership goal for its member companies—each to invest 2 percent of annual R&D expenditures in engineering colleges and universities.

Since 1982 AEA has tracked over $353 million given by its member companies to engineering and computer science programs. This likely represents about 20 percent of what is actually contributed, especially if personnel time, facilities, and equipment are calculated. The Council for Financial Aid to Education (CFAE) data show industry contributions to higher education on a consistent rise:

Support by Businesses/Corporations

Support Type	1977-8	1981-2	1982-3	% Change 81-2 to 82-3	% Change 77-8 to 82-3
All Types	$508 M	$976 M	$1.112 B	+13.9%	+118.9%
Faculty Compensation	$185 M	$284 M	$ 334 M	+17.6%	+ 80.5%

In addition to many on-going programs, initiatives below are representative of significant new industry investments:

Bell Labs	Four-year $3.5 million program to support doctoral students in telecommunications fields.
Control Data	$6 million PLATO computer-based pre-engineering courses and donations of microcomputers to 110 colleges and universities to aid faculty productivity.
Exxon	$15 million to support engineering departments at 66 universities for teaching fellowships, faculty grants, and faculty development in six traditionally black engineering colleges.
Hewlett-Packard	$6 million to support 54 fellowship-loans for U.S. citizens to become engineering professors through AEA's Faculty Development Program.
IBM	$50 million to develop and improve engineering programs in manufacturing systems and $1.2 million to engineering departments for support of 150 postdoctoral and graduate fellowships.

Industry research dollars have steadily increased as well—300 percent from $112,952 million in 1975 to $325,581 million in 1982. Between 1980 and 1982 alone, industry research funds increased 160 percent. A CFAE survey shows a 56.5 percent increase in dollar value or a 4 percent increase of all corporate-funded university department research grants between 1980 and 1982.

Some of the increase in research dollars can be attributed to the formation of industry research collaboratives. SIA's Semiconductor Research Corporation (SRC) began with $6 million in 1982. Increasing to over $11 million in 1983, SRC's contracts with universities are for semiconductor research that is typically too long-term or speculative for a single company or university. Other collaboratives, such as the Microelectronics and Computer Technology Corporation (MCC) funded by some 18 companies, have their own pool of researchers, but both direct and overflow contracts will seep into university coffers.

In spite of a year's delay in issuing 1981 ERTA regulations, it seems clear that the federal tax incentives stimulated corporate equipment donations. In 1980, for example, CFAE reported that 19 percent or $64.7 million of all corporate gifts went towards research. In 1982—after the passage of ERTA—24 percent or $114.6 million went for research. Types of corporate gifts also shifted during this period towards increased donations of products. Of $1.2 billion donated, a record $96 million were in product gifts.

A 1984 AEA survey of six universities in the states of Oregon, Texas, and Colorado determined research donations increased 2 1/2 times between 1982 and 1983—from a total of $944,762 in 1982 to $3,302,370 in 1983. One Oregon university which advertised the R&D tax deduction widely to companies had a 12-fold donation increase—from $24,500 in 1982 to $314,000 in 1983.

AEA's Foundation has publicized and promoted federal R&D tax incentives to Association companies. Whether guided by these or the "2 percent of R&D goal," corporations have clearly come up to a higher level of financial commitments to engineering education in the last three years.

Public Information Role

Over the last three years, AEA company executives and AEA staff have spoken at countless conferences for government, industry, and education audiences and at AEA Council events. They have written articles for education and trade magazines; been guests on radio talk shows, public television, and evening newscasts; and been consistently quoted in national and local newspapers and trade journals on engineering and technical education issues.

While the impact of this effort cannot be specifically measured, these activities merit substantial credit for raising the consciousness of industry and educational leaders about the problem. Many legislators who have talked with executives at AEA's annual Capital Caucus in Washington, D.C., heard AEA testimony on state and federal bills, and been individually visited or hosted by AEA executives and staff have been turned toward active assistance on educational issues of importance to Association members. Fair gains in the passage of state education bills but only modest success at the federal level, however, suggest AEA needs to work harder in the legislative arena to inform and communicate.

Model Program: Guidebook on Model University-Industry Engineering Programs

In April 1982 AEA published a *Guidebook on Model University-Industry Engineering Programs* to stimulate companies to replicate them. The document contains descriptions of over 45 model programs, including names and phone numbers of key contact people, in areas such as loaned faculty, faculty assistance grants, engineering programs for females and minorities, and R&D grants. It provides a checklist for companies to use in selecting institutions to support financially. A form is also included to help companies conduct in-house surveys to determine alma maters of their engineering workforce. In addition, the names, addresses, and phone numbers for deans of all ABET-accredited programs are provided.

Complimentary copies of this guidebook were sent to all AEA members. Second copies for a modest reprint charge continue to be sold two years later—evidencing some value in "guiding" the way.

Model Program: Guidebook on Curriculum Requirements for Electronic Technicians

In November 1980, a year before AEA launched its national program, AEA San Francisco Council executives and Santa Clara County community college electronics instructors developed a guidebook entitled *Curriculum Requirements for Electronic Technician Training*. Reviewed and endorsed for national distribution by AEA's Human Resources Committee, the guidebook is intended as a planning document. It provides content topics in four courses: AC, DC, Digital, and Semiconductor, and lab objectives in the first two. Rated Value Scales (ranging from 1 for *student must know,* to 4 for *unnecessary in this class)* and Depth of Emphasis Scales (ranging from 1 for *synthesize,* to 4 for *recognize)* are given to show one AEA Council's perspective. The document has been used by industry members of education advisory committees to influence curriculum changes, by educators and industry executives to determine what companies want students to learn, and by those who use it as a baseline for starting new electronic technician training. AEA's Los Angeles EE Committee is currently working to update the document.

Model Program: Job Training Under State "CWETA" Program

Between 1980 and 1982 AEA staff managed the AEA Training Consortium in Santa Clara Valley. Funded for $750,000 by California's Worksite Education and Training Act (CWETA), which AEA executives had helped enact, the program provided education and training to upgrade electronics assemblers and test operators into technician jobs and to "backfill" entry-level jobs with youth and unemployed or underemployed people. In total 119 employees from four AEA electronics firms completed upgrade training, lasting nine months to one year. An additional 85 received three-to-six month entry-level skills training. AEA managed the Consortium on behalf of the four companies with two community colleges, one high school district, and one community-based group.

The job training program proved successful, and the participating companies felt the effort worthwhile. The downside was the difficulty dealing with a state bureaucracy in a new program where regulations were continually developed. A major barrier was that state staff had little-to-no working knowledge of the electronics industry. The effort, however, helped subsequent state programs and similar projects to be more practically based, less regulated, and less burdened with extraneous reporting.

Model Program: Job Training Information Link to Companies

In October 1983 the federal Job Training Partnership Act, (JTPA) the second generation of 1973 CETA legislation, was funded. Its purpose is to train low-income, unemployed people to enter the labor force. AEA acts, along with many other industry and educational associations, as an informational link to its members on the aims and goal of JTPA. It is too early to assess the assistance AEA provides.

Model Program: Japan Research Fellowship Program

A pilot effort by AEA begun spring of 1984, the Japan Research Fellowship Program fosters mutual appreciation of the technological capabilities of both the U.S. and Japan. A few U.S. universities currently send business and management majors to study in Japan. Only a couple send their technical students.

Six American graduate students in electrical and computer engineering and computer science—from Carnegie-Mellon, U.C. Berkeley, Princeton, U.C. Santa Barbara, and Cornell—are part of this AEA effort. They completed nine weeks of intensive Japanese language study at Cornell and began work in research labs of NEC, Intel-Japan, or Oki Electric. In Japan, they receive guidance on development of a research paper and Saturday cultural seminars from a visiting U.S. engineering professor. AEA member companies funded Japanese language study. Japanese host companies pay for transportation, housing, and living costs while in Japan. The U.S. Department of Commerce matches AEA funds to pay for the faculty coordinator in Japan.

AEA's program is unique: (1) It reflects a broad national perspective in that it "umbrellas" students from many universities; (2) It broadens the experience base of each student who shares experiences with other students in AEA Saturday seminars in Japan; (3) The research insights gained can be transferred to the broader U.S. industry through AEA-published research papers; and (4) The Japanese language component builds a cultural sensitivity that will enhance students' value as employees in whatever company or university they join.

The progam has been enthusiastically received by industry, education, and government. It provides a modest yet substantive model of how Japan and U.S. industry can combine efforts to improve relationships.

Model Program: Orange County Career Education Project

Begun in 1980 by the Orange County AEA Council, this career education project focused on community college electronics technicians. Posters, a filmstrip, and brochures were produced as counseling tools to interest students in technician training and careers. The program in 1982 branched direction to foster Adopt-A-School programs in area high schools. It also provides a forum where Orange County educators and electronics executives exchange views on vocational education and develop company-school partnerships to assist student placement, curriculum development, etc.

Model Program: Community College Instructor Bank

A community college electronics instructor on sabbatical with AEA developed a model "Electronics Instructor Bank." The Bank's purpose was to help alleviate faculty shortages by identifying technically skilled personnel in AEA member companies who wanted to teach electronics part-time in Santa Clara County community colleges. During the two years AEA maintained the bank, 256 industry people applied, 195 referrals were made, and at least 15 applicants were placed in area colleges. In May of 1983, the Bank's operation was assumed by Foothill College's SEARCH Consortium as part of a statewide, computerized instructor bank.

ESTABLISHMENT OF A DATA BASE

Survey: Technical Employment Projections

In 1981 AEA conducted a national survey of electronics and information technology companies to determine expected job growth in 20 technical job categories over five years. Forty-eight percent—or 610 respondents—made projections. AEA repeated the survey in 1983; 39 percent—or 815 respondents—participated.

The survey reports have been used extensively by educational administrators to justify expansion of technical and engineering programs and courses. They have also been useful as planning documents for companies considering plant location or expansion. The data on needs for electrical and computer engineers, when juxtaposed against projected new graduate supply, have stimulated industry involvement in engineering education programs. The evidence of steady job growth has helped dispel the "boom or bust" 1970s' legacy. It has helped focus federal and state legislative attention on the need to increase engineering and technical education budgets and faculty salaries.

"Matrices of Need" by Universities

To organize industry action, AEA identified over the last two years a "Matrix of Need" for electrical and computer engineering and computer science departments at 92 universities located in AEA Councils across the country. The matrices note the number of BS degrees produced, the number of faculty vacancies and average starting salaries, and broad priorities of need for faculty grants, graduate student support, and equipment. Based on these matrices, regional plans are developed by AEA industry fundraising executives to guide company donations to areas of most critical need in amounts likely to make a difference.

Membership Survey: Continuing Technical Education Needs

Keeping the present workforce current is a logical, complementary goal to increasing the production of quality new graduates. AEA conducted a survey in April 1984 to determine members' interest in the Association undertaking a continuing technical education activity.

Questionnaires mailed to 130 representative-sized companies resulted in 85 responses. The results underpin an effort beginning fall 1984 to compile AEA Council Guidebooks to inform companies of university media-based courses in engineering and computer science. In addition, based on survey response, AEA will offer at a discount to its members videotaped shortcourses from 22 universities offered through the Association for Media-Based Continuing Education for Engineers (AMCEE). Other continuing education directions are outlined in Section III.

LEGISLATIVE ACTIVITIES

Federal: R&D Tax Credits

A cornerstone to AEA efforts at the federal level to improve engineering and technical education has been tax incentive legislation that seeks to leverage public dollars with private. Traditionally federal educational matters are considered by educational committees. Using federal tax policy to solve a national education policy is largely unprecedented. AEA's unique approach has brought some members of Congress to new awareness of engineering education problems.

The "High Technology Research and Scientific Education Act," introduced in 1983 as S.2164 and H.R.3098 and in 1984 as S.2165 and H.R.4475, has not yet passed and will be reintroduced in the next Congressional session. To upgrade scientific and engineering university laboratories, the bill extends the R&D tax deduction in ERTA to include donations to colleges of customer-owned and newly manufactured instructional and research scientific and technical equipment and software. Since research dollars augment faculty salaries and enrich academic environments to make teaching more attractive, the bill creates a new 25 percent tax credit to encourage corporate research with universities. And to encourage students to continue on to graduate study and teaching careers, the legislation excludes from a student's taxable income loans "forgiven" when the student graduates and teaches.

AEA executives have testified and lobbied this bill before Congressional committees and at two AEA Capital Caucus events. In January of 1984 AEA formed a coalition with engineering deans, college presidents, and some 26 national educational associations to lobby the legislation. This new alliance has been helpful with key legislators from states where AEA has few or no members.

Dr. Stephen Kahne, Dean of Engineering at Polytechnic Institute of New York, and an IEEE Vice President, wrote last April about the value of the effort:

> The contribution AEA is making to the health and strength of engineering education in the United States is most effective. The CEO/Deans coalition . . . shows promise of being an extraordinarily powerful and constructive force in the policy arenas in this country. . . . Please convey our appreciation to the officers and directors of AEA.

Federal: Employee Educational Assistance Act

In 1983 an exemption from taxable income granted in 1978 under Section 127 for employer-provided-and-paid-for educational assistance expired. The combined employer-employee contribution amounts to about 16 percent tax on educational assistance. The exemption loss runs counter to what many feel should be part of a national policy—encouraging continuing education of all workers. At a time when workers are predicted to undergo eight career changes in one lifetime, this loss is extremely harmful to lower-level employees trying to upgrade their skills. In October 1984 AEA and some 30 other industry and education groups were successful in reinstating the exemption through 1985 for the first $5,000 with FICA and FUTA deducted on dollars exceeding this amount.

Federal: Immigration Bill

The original House and Senate versions of the Immigration and Reform Act of 1983 required all foreign students to return to their homelands for two years after graduation before reapplying for immigration to the United States. These foreign-born graduates of U.S. colleges and universities are presently the mainstay supply of new engineering faculty. And while increased defense budgets draw U.S.-born graduates toward defense contractors, civilian non-defense companies must increasingly recruit some foreign graduates.

AEA worked extensively to get the bills amended. San Francisco AEA industry executives hosted Congressman Romano Mazzoli (D-KY) for one day, educating him about the impact of the return-home provision. Students with state-of-the-art education will tend to seek jobs in other industrialized countries if they cannot work in the U.S. Through the efforts of Senator John C. Danforth (R-MO) and Congressman Barney Frank (D-MA) the bill was successfully amended to exclude graduates in engineering, math, computer science and natural science who have jobs the Department of Labor certifies no U.S. applicants are available to fill. The amendment waiver prevents giving our international competitors an economic advantage in receiving these foreign graduates.

Late spring of 1984, the AEA-backed House amendment survived a last minute challenge when a Congressman withdrew an amendment to delete the waiver for industry jobs. This success was achieved by lobbying of industry groups through AEA and with support from key members of Congress.

AEA's strong position on this bill has heightened congressional awareness of the need for more electrical and computer engineers and of the dire situation engineering departments face trying to recruit U.S. citizens for faculty jobs. The Immigration Bill amendment dramatizes that the federal government should not worsen the situation by deleting a major source of academic recruitment and a small but important one for industry as well.

Federal: Add Engineering to NSF Mission Statement

The absence of the word *engineering* in the NSF Act of 1950 draws an artificial distinction between the primary NSF mission of basic scientific research and engineering research. Yet the situation in today's university research labs increasingly blurs the line between basic science and fundamental engineering research. Creation of industry collaboratives, such as the SRC and the MCC, evidence an unmet national need.

Rather than create a new bureaucracy, AEA joined with groups such as the National Society for Professional Engineers and the Engineering Deans Council to amend the Act to include engineering as part of its mission.

Industry's willingness "to stand up and be counted" on this somewhat controversial issue helped the bill's passage through Congress. Vetoed by the President, the bill will be reintroduced in the 99th Congress.

State Legislation: Technical Education

Federal legislative action helps improve engineering and technical education most directly in the areas of research and tax policy. Education is still most broadly addressed in state legislatures and educational policy bodies. AEA began to work the state problem in 1982 by establishing educational legislative subcommittees in California and Oregon. These states have laid the groundwork for development and/or enactment of bills and "boiler-plate" policies that can be replicated by other states, such as:

California: UC Regents Raise Engineering Faculty Salaries

In June of 1981 AEA played a small but timely role in bringing the University of California Regents and Administration to new awareness of the serious need to increase engineering faculty salaries in the UC system. While plans had been made to provide a separate faculty salary plan for business like medicine and law, engineering was at the bottom of the list of concerns.

Through AEA discussions with UC Administration and lobbying the UC Regents (a member of AEA's Blue Ribbon Committee was a UC Regent), a report was presented in November 1981 that recognized faculty retention and recruitment problems in both business administration and management *and* engineering. A separate salary plan for engineering was adopted by the Regents in July of 1982 for new faculty, for all others July 1, 1983.

California: California State University Engineering Faculty Salaries

In 1982 AEA testified before an Assembly committee that eventually passed AB 2023. This bill authorized the California Postsecondary Education Commission to undertake a year-long study to determine the seriousness of engineering faculty retention and recruitment problems at the 13 California State University (CSU) campuses with engineering programs.

The study documented the problem and AEA renewed efforts to remedy it during 1983. With AEA executives and CSU administrators and deans of engineering, strategy laid behind the scenes led toward signing of a first-of-its-kind provision in a faculty union contract. This provision built in a mechanism to augment salaries in hard-to-hire disciplines with a "market condition salary supplement" (MCSS).

In 1984 AEA worked through the Governor's office and the Department of Finance and with key Assembly and Senate leaders to augment the CSU budget with $11.3 million to fully fund MCSS. The Governor augmented only $1.9 million to the 1984-85 budget, with the assumption that a prior 10 percent across-the-board salary increase could be reduced enough for all professors to give more to hard-to-hire faculty. Currently the administration and the union are at a bargaining impasse, requiring arbitration. Assistant professor salaries for 1984 range from $20,149 to $24,224. The 10 percent increase—should it be successfully negotiated—will set a range for a new assistant professor with a Ph.D/EE from $22,164 to $26,646. This remains inadequate.

As the Governor's intention not to fully fund MCSS became known, AEA worked with other educational and professional groups to add the provisions contained in the MCSS to the State's Education Code to create a statutory base for salary supplements. Carried in SB 2238, the bill was signed into law September 1984.

California: Funding Mechanisms for Research Facilities

In 1983 AEA worked for passage of SB 1067 to authorize issuance of revenue bonds or negotiable notes to fund construction of facilities for use as research and educational centers dedicated to "high technology fields of engineering, computer science, . . ." SB 1067 was chaptered in 1983.

Results: 1984-85 (tentatively approved)

- $41.5 million to fund construction of an addition to the Life Sciences building at UC Berkeley.
- $18.2 million to fund construction of a new engineering building at UC Santa Barbara.

Proposed: 1985-86

- $34.8 million for an engineering building at UC San Diego.
- $4.1 million for an engineering lab facility at UC Irvine.
- School of Engineering and Applied Science expansion at UC Los Angeles; detailed costs being developed.

California: Tax Incentives for Higher Ed Equipment Donations

In 1983 AEA lobbying and testifying was instrumental in passage of AB 430. This bill—which will sunset June 1985—extends a currently permissible deduction for corporate donations of new research equipment to higher education institutions (including community colleges) to include donations of instructional equipment as well.

Modeled on AEA-developed federal legislation, the increased deduction is equal to a donor's cost plus one-half unrealized profit or whichever is less. The total benefit to California postsecondary schools is not yet known. This legislation is serving as a model for other states.

In 1984 others began efforts under a new bill, AB 3431, to extend AB 430 and AB 3194. The bill provides tax incentives for donations to K-12 schools and changes the tax deduction to a tax credit for community college contributions. AEA negotiated several amendments to AB 3431 that eliminated the vague standard requiring equipment be "state-of-the-art" and deleted a requirement that would in effect require authorization for donations to be approved by the appropriate state agency—a requirement that runs counter to local industry-education partnerships. The amendments also prevented the addition of burdensome tax reporting requirements. AB 3431 passed both the Assembly and Senate but was vetoed by the Governor.

California: Improved Tax Incentives for Higher Ed Donations

In 1983 AEA worked to pass AB 1022, a key part of Association strategy to improve engineering education in California's postsecondary institutions. The bill moves several steps beyond AB 430. Key features are:

- Tax credit of 25 percent of company costs to donate full-time personnel to teach in post-secondary colleges and universities in physical, biological, and computer science.
- Tax credit of 25 percent of company costs associated with donating labor charges for servicing and repair pursuant to a contract between the donor company and institution and in tandem with a hardware donation.

- Deduction in current law to apply to donation of customer-owned equipment three years or newer for teaching, research, or research training in physical or biological sciences, engineering, and computer science.

The bill failed in the legislature. A legislative effort may be re-launched in 1985.

California: Increased Research and Graduate Education

In 1981 AEA was actively involved in passage of legislation which established the industry-university research MICRO Program at UC campuses. AEA staff and company CEOs contacted the Governor and legislators during particularly volatile periods of the proposal's development. After three years, MICRO has received increasing industry participation—from 25 companies and 31 projects in 1981-82 to 40 participating companies and 58 research projects in 1983-84.

Year	State Funds	Industry Funds	Total Support
1981-82	$ 980,000	$1,344,000	$2,324,000
1982-83	$1,940,000	$3,215,000	$5,155,000
1983-84	$2,080,000	$2,216,000	$4,296,000
1984-85	$4,080,000	n.a.	n.a.

California: Community College Voc Ed and Job Training

AEA participated actively during 1983 and 1984 to develop policy considerations and refined statutory criteria for AB 2076. This bill proposed to establish a Community College Job Training Improvement Program to aid vocational and job training program planning. Emphasis was on funding pilot projects to determine current and long-range job needs of specific industries. The bill was vetoed by the Governor.

In 1984 AEA worked for passage of AB 3938 to further two important improvements in vocational education: (1) contract instruction, wherein a company contracts with a college to provide specific course content and instruction and pays full costs; and (2) voc ed instructor in-service—update training and work experience to keep faculty technologically current. AB 3938 provides $100,000 for a study of contract instruction—i.e., defining which Education Code statutes inhibit it as well as how to ensure delivery of quality education where credit is awarded. The bill provides $500,000 for community colleges to identify curricular areas affected by changing technology and provide faculty in-service to keep them up to date. This legislation has been approved by the Governor; additional funding may be augmented in next year's Community College budget.

Oregon: High Technology Consortium

In 1982 a joint effort of industry, education, and government led by AEA resulted in formation of the Oregon High Technology Consortium. Its purpose is to work with the Oregon Educational Coordinating Commission to improve the quality of high technology postsecondary education.

The Oregon Legislature and the Governor appropriated $500,000 to fund Consortium programs during 1982-83 and another $1 million during 1983-84-85, provided the monies are matched by industry dollars. AEA companies, using the Association's Foundation, have raised $1,310,974 to date—less than $200,000 short of the overall $1.5 million goal. Tektronix has given a large share to vanguard the effort—some $904,000.

Oregon Consortium objectives emphasize quality over quantity in upgrading high-tech education. Dollars are distributed by criteria: (1) excellence of the educational program; (2) geographic proximity of educational resources to companies; (3) focus on electrical and computer engineering and computer science initially; and (4) coordination throughout public and private sectors.

Some examples of projects authorized by the Consortium are:

- Portland State University—$400,000 for new faculty in VLSI and signal processing and electrical engineering faculty development
- University of Portland—$150,000 for new faculty with emphasis in computer architecture
- Clackamas, Linn-Benton, and Portland community colleges—$75,000 for special projects.

Oregon: Improvement in Engineering Education and Faculty Salaries

In 1982-83 AEA was a key force in passage of HB 5007. This bill froze tuition levels at state colleges and universities and provided approximately $3 million to improve engineering programs and $200,000 to enhance faculty salaries. A valuable byproduct of this effort was development of a strong industry/education/government coalition. AEA became recognized as a valuable resource by both the Oregon legislature and the higher education community.

Oregon: AEA/Oregon Legislative Agenda for Education

The following framework has been developed by the AEA/Oregon Education Subcommittee and will guide efforts during the 1985 legislative biennium:

- A faculty salary enhancement package.
- A state-wide video link between public and private colleges.
- An Oregon Department of Education study on distribution and effective use of donated computer equipment.
- A new Oregon State University engineering facility.
- A new Portland State Ph.D. and continuing education program in EE/CE.
- An Oregon Education Center housed at Portland Community College's Rock Creek Campus offering a full range of engineering courses.

New Jersey: Matching Program for Fellowships to Develop Faculty

Efforts by AEA company executives and staff have resulted in the co-sponsorship by the New Jersey Governor's Commission on Science and Technology of a fundraising effort to raise a minimum of $1.8 million from industry. AEA will work with the Commission and educational groups to pass legislation authorizing a state dollar match for AEA funds raised for fellowships and equipment donations through the Foundation.

State Legislation: Elementary and Secondary Education (K-12)

Oregon played a peripheral role on K-12 governance proposals in 1982-83. They proved too politically sensitive for the legislature to resolve during the session.

In 1983-84 AEA worked in a minor way to ensure that California bill AB 803—one aspect of which is to develop courseware (i.e., software which teaches the user) guidelines for developers—would not contain requirements detrimental to this beginning industry segment. During 1984 AEA has been represented on a Department of Education Software Standards Committee. Present efforts are directed toward keeping proposed guidelines from becoming regulations and to prevent the state from requiring certain licensing and duplicating rights.

Experience with software standards and tax incentives to encourage corporate donations of computers to K-12 schools indicates that these issues require extensive analysis by experienced educational policy specialists before AEA positions should be taken. Tax incentives for computer donations to K-12 appear to be helpful. The legislation must be carefully drafted to reflect cognizance of the need for operational software, teacher training, and availability of compatible, appropriate student courseware. For these reasons, caution is recommended for AEA councils that wish to take positions on K-12 legislation. Executives are urged to support substantive and readily defensible proposals intended to increase faculty salaries, raise graduation standards, etc.

ELECTRONICS EDUCATION FOUNDATION (EEF)

AEA's Electronics Education Foundation (EEF) was established in November of 1981 as a private nonprofit 501 (C)(3) public benefit foundation. The AEA Board authorized it for two purposes: (1) to stimulate the flow of new monies from companies directly to universities for engineering and technical education; and (2) to initiate corporate contributions which "flow through" EEF to universities for special programs which gain impact under the Foundation "umbrella," such as AEA's Fellowship-Loan Program and Faculty Grants.

The AEA Blue Ribbon Committee on Engineering Education acts as a National Advisory Committee to the Foundation. The current Board and Officers of EEF are:

Chairman: William J. Perry, Partner, Hambrecht & Quist
Jan J. Collmer, President, Collmer Semiconductor, Inc.
E.E. Ferrey, President, American Electronics Association
Glenn E. Penisten, Chairman, AMI/Gould, Inc.
William R. Thurston, President, GenRad, Inc.
Karl Willenbrock, Green Professor of Engineering, SMU

Officers: Pat Hill Hubbard, President
William H. Phillips, Jr., Secretary/Treasurer

Fellowship-Loans to Develop New Faculty

In early 1982 EEF set a goal to raise 200 fellowship-loans to fund the doctoral study of U.S. citizens who want to teach electrical and computer engineering and computer science. The 200 figure was recognized to be a fraction of the total needed throughout the country but still substantive enough to stimulate the start-up of similar programs by others. To date 123 fellowships have been committed, including the 54 AEA Fellowships funded by Hewlett-Packard. Through EEF, 48 companies and individuals have committed 69 fellowships to 29 universities for a total of $3,230,288.

Companies or individuals commit four years of support through EEF—$52,000 for a public or $76,000 for a private university—to fund a maximum of four years of doctoral study for a U.S. citizen. A $10,000 living stipend is provided for each of the four years and annual tuition up to $3,000 for a public and up to $9,000 at a private university. A university-appointed faculty committee selects recipients according to criteria set up by EEF. Essential requirements are that candidates be top students and genuinely interested in teaching careers. Given equally qualified applicants, universities are encouraged to select women and minorities. The university agrees to provide two years of a part-time teaching or research assistantship to augment AEA company donor funds. The student agrees to work at least one summer in industry. Each fellowship carries the name of the donor company or individual.

Increasingly the fellowship program is viewed as significantly helping to redress the faculty shortage problem. One professor maintains that engineering students view AEA fellowships as evidence of strong industrial support for the importance of engineering professors to the country. He believes even some of those turned down as AEA recipients are stimulated to pursue doctoral studies and academic careers anyhow.

The following excerpt from a letter reflects the enthusiastic response from the university community:

> ". . . the AEA Fellowship Program . . . is an excellent method for encouraging and training the future faculty in electrical and computer engineering/science. I hope that your efforts will continue beyond the goal of 200 applicants that you have set and that you will continue this program on a steady-state basis."
>
> John G. Proakis, Chairman
> College of Engineering
> Northeastern University

In a letter to Augat, Inc., the fellowship recipient reflects the financial impact industry funds typically have on students:

> "I came back to college after spending 10 years in industry working as a manufacturing engineer and N.C. programmer. I . . . came to a decision several years ago to go back to school to study for advanced degrees in computer engineering. My grades reflect my determination to do well. I have a straight A average in my courses at the University.
>
> This was to be my last semester as we could not afford for me to continue. I am married and have two children. Your fellowship came to me and has given me another chance to continue on towards a Ph.D. This was unexpected and hence my sincere gratitude and appreciation to your firm. . . . Without the fellowship, I could not have continued my education. With it, I hope to become a more valuable resource and play a part in upgrading education and industry in this country."
>
> Donald A. Joy
> March 26, 1984

And there is evidence of growing prestige associated with selection as an AEA fellow, reflected in the following excerpt from a student letter:

> "As a measure of my dedication to teaching as a profession, I declined a NSF fellowship in order to be an AEA fellow. I intend to be very diligent in my studies at Stanford in order to develop this great opportunity and to justify the support. . . ."
>
> David Allee
> August 1984

Faculty Grants to Retain and Recruit Faculty

Three to four years will pass before new teachers begin to flow through the AEA Fellowship-Loan Program pipeline. The Foundation, therefore, designed a Faculty Grant program whereby companies can help retain and recruit professors today. The impact of these grants has been far-reaching beyond retention and recruitment. Small dollars have stimulated extensive curriculum development (See Addendum K for sample use). To date 71 faculty grants have been committed through EEF by 56 companies and individuals to 27 colleges across the country for a total of $725,175.

Grants range from $5,000 to $10,000 annually and carry the name of the donor company. They are designed to (1) augment the salary of a faculty member about to leave for a higher industry salary; and (2) make more attractive an authorized vacancy where the salary is too low to attract qualified candidates. EEF negotiates with the Dean of Engineering on behalf of the donor company to develop a contract for specific faculty services to be performed. The intent of this contract is to augment faculty salaries without making the performance requirements burdensome. This contract also prevents the university from taking out an administrative fee for overhead that can range as high as 40 percent and redistributing the funds throughout the university.

Equipment Purchases and Service Contracts

The Foundation assists companies in distributing multiple equipment donations to universities. EEF develops a Request for Proposal (RFP) with the company, distributes it to selected universities, and based on the submitted proposals determines with the company where the equipment is likely to have greatest impact.

EEF also encourages companies to contribute cash for equipment grants to the Foundation for "pass through" to colleges, and for much needed service and maintenance of equipment. To date 22 equipment grants have been committed through EEF by 14 companies to 13 universities for a total of $249,191.

Miscellaneous Grants

- Student Aid
  Four companies have funded student scholarships and other kinds of student aid for a total of $205,200.
- Discretionary Grants
  Seventeen companies have donated unrestricted grants for a total of $31,600.
- Auditing Services: Price-Waterhouse
  Price-Waterhouse donates auditing services to the Foundation, offsetting the need to raise funds for this service.
- AEA
  In addition to providing seed money of $105,000 to establish and operate the Foundation, AEA provides executive management, staff for grant and fellowship management, and other assistance in accounting, mailing services, etc. All corporate funds are "passed through" EEF to universities. Foundation operational costs are paid by the interest on contributions generated on "float"—i.e., before funds are paid to universities.

The Foundation has almost reached the $7 million mark in contributions committed. Its broad base of industry support acts as strong underpinning for state and federal legislative efforts and serves as evidence that industry is "doing its part."

AEA Engineering and Technical Education Directions

Computer Science

Background:

In July of 1980 the Computer Science Board of the Association for Computing Machinery (ACM) sponsored a meeting at Snowbird, Utah, of 56 U.S. and Canadian department chairs from colleges awarding Ph.Ds in computer science. They issued the "Snowbird Report," which described explosive growth of student interest in the computer field without parallel growth in college computer science departments. They spotlight the acute focal point as the doctoral level. Key aspects of the crisis are:

- Only 25 percent more Ph.D/CS degrees are awarded today than a decade ago despite enormous industry job growth.
- Fewer than 100 new Ph.D/CS graduates were available to fill more than 650 known CS faculty vacancies.
- Undergraduate enrollments have doubled since 1975 with lab and facilities remaining relatively fixed.
- Only 32 new faculty positions or 2.8 percent of all faculty slots were filled between 1975 and 1979, while CS graduate student demand increased 20% annually.

U.S. Production of CS Ph.Ds and Faculty

Year	Ph.D/CS Degrees	Number of Faculty
1973	208	n.a.
1974	203	862
1975	256	878
1976	246	843
1977	208	881
1978	214	938
1979	248	958
1980	265*	n.a.
1981	272**	n.a.
1982	261	n.a.
1983	260**	n.a.
1984	250***	n.a.

*Estimate by ACM
**Estimate by AEA
***Estimate by CS Board

Source: *Communications of the ACM*, June 1981

The Snowbird Report cites a decline in the quality of students applying to Ph.D/CS programs. It notes that industry "skims off the cream before they enter graduate school."

While NSF, BLS, and others consistently agree that computer science job growth is outpacing graduate supply, no one seems to know how serious the imbalance is. AEA's survey projections forecast five-year (to 1987) total job growth of 102 percent for programmers/analysts. Yet it appears impossible to project supply, because the degree data are amorphous:

- An estimated 2,200 higher education departments have "computer" in their titles. Some universities have more than one program. No one source has a complete list.
- Data on supply of CS graduates do not include math, physics, or economics degree holders—those likely to cross disciplinary boundaries and take computer-related jobs.
- NSF only recently began to count computer science professionals as a separate category. Even now, in classifying academic departments, NSF labels departments with compound names by the first adjective. If a department is titled "EE/CS," NSF data are categorized under "EE" only.
- Some supply data are reported only for Ph.D.-granting departments carrying the name "computer science." Departments of math or business with computer options are omitted.
- Matching supply data to specific job categories is difficult. A programmer job may be filled by a holder of an associate, bachelor's, master's, or doctoral degree.

Given these supply data problems, the best picture of computer science supply-demand has been presented by John Hamblen of the University of Missouri-Rolla's Computer Science Department. On assignment to the U.S. National Bureau of Standards' Center for Applied Mathematics, Hamblen separates demand by degree level and high and low degree supply through 1989.[41]

Annual Demand for Computer Manpower by Degree Level

Degree Level	Demand Estimate
Associate	21,000 - 32,000
Bachelor's	43,000 - 65,000
Master's	27,000 - 41,000
Doctorate	1,000 - 1,600

High and Low Estimates of Degrees Awarded in Computer Related Fields, 1978-1989

Year	Bachelor's	Master's	Ph.Ds
1978-79	9,[illegible]0 - 13,000	3,100 - 3,400	236 - 326
1979-80	11,000 - 16,000	3,600 - 4,000	240 - 307
1980-81	15,000 - 22,000	4,100 - 4,500	252 - 295
1981-82	18,000 - 26,000	4,700 - 5,100	259 - 278
1982-83	21,000 - 30,000	5,200 - 5,600	267 - –
1983-84	24,000 - 35,000	5,800 - 6,200	275 - –
1984-85	27,000 - 39,000	6,300 - 6,700	283 - –
1985-86	31,000 - 44,000	6,900 - 7,300	291 - –
1986-87	34,000 - 48,000	7,400 - 7,900	299 - –
1987-88	37,000 - 53,000	8,000 - 8,400	307 - –
1988-89	40,000 - 57,000	8,500 - 9,000	317 - –

Hamblen points out that associate degree graduates by 1979 had already exceeded job needs by sorne 32,000. He commends the smart two-year postsecondary schools which wisely stopped offering terminal associate CS degrees. Instead they encouraged students to take an "articulated" two-year undergraduate curriculum with the prospect of pursuing bachelor degrees.

The supply of bachelor degrees in CS, Hamblen suggests, will balance demand by 1985-86. The estimated 24,037 bachelor degrees produced in 1981-82 indeed fit Hamblen's middle range 1982-83 demand projections. He suggests several results of supply-demand balance at the bachelor level:

- Starting salaries for bachelor degree holders will level off or drop.
- Weak bachelor degree holders will compete with strong associate degree holders for jobs.
- Salary differentials for master's degrees vs. bachelor's will increase.
- Graduate enrollments will increase as job options narrow for bright bachelor-degree graduates.

Hamblen projects extreme shortages of master's degrees in CS into the 1990s. He believes the master's in CS will "eventually replace the traditional MBA . . . unless MBA programs incorporate more work in areas of computer information systems." Peter Denning, former President of ACM, underscores Hamblen's concern about CS faculty shortages that compound a decline in educational program quality and restrict research activities.

In 1981 Denning counted U.S. and Canadian CS department ads to recruit new faculty; he found 273 open positions. Optimistically projecting that 45 percent of the 272 Ph.D. graduates would take faculty jobs, Denning predicted 150 of these slots would remain vacant.

More recent data come from the CS Board meeting in September 1984. The Board estimates 189 faculty vacancies in the 90 Ph.D.-granting CS departments alone. Retirement is expected to exacerbate the problem in a decade, since the average age of CS faculty in these departments is currently 54 years.

The Snowbird Report calls for increased industrial and government support for CS doctoral fellowships to develop faculty, with stipends sufficient to reduce attraction of industry jobs at the bachelor level.

AEA Action:

- Emphasize funding additional fellowship-loans to develop new computer science faculty.
- Encourage national accreditation for computer science departments to improve data reporting and help ensure quality education through review of curriculum, labs, equipment, and faculty.

Continuing Technical Education

Background:

Concomitant with AEA's effort to improve the supply of new engineers and technicians from U.S. schools is the need to keep the present workforce current. The expanding depth and diversity of technological innovation makes the half-life of a working engineer an estimated five years. This, coupled with the fact that 70 percent of the engineering workforce is over 35 years of age, calls for a new direction of effort.

AEA Action (Approved by AEA Board May 1984 as three-year project):

- Foster company use of ITV (media-based) instruction by distributing Council guidebooks on university engineering and computer science ITV courses and by offering AMCEE taped short courses to AEA companies at a discount.
- Establish a national technical education committee to identify course topics, content, and instructors and pilot delivery of one-day technical update courses face-to-face and/or as videotapes.
- Assess feasibility for 1986 of delivering one-day technical update courses via satellite to member companies.

Job Projections Survey

Background:

In 1981 the need for an AEA engineering education program was verified by a survey of AEA companies which determined five-year projected technical job growth. In addition to quantifying the degree of need, the survey data were collected to help colleges justify expansion of courses and physical plants to meet the need. AEA repeated the survey in 1983.

At the February 1984 National Research Council symposium, AEA, NSF, and BLS found common ground on their projections of demand and new supply of graduates from colleges. They differed on ways the country should best fill the shortfall. It's no longer warranted, therefore, to duplicate NSF and BLS efforts with a third AEA national survey.

Company job projections on a regional or state basis, however, are greatly needed. Such data are especially necessary for effective community college vocational education course/program planning and for job training undertaken by groups such as the Private Industry Councils.

AEA Action:

- At the request and with the assistance of AEA Councils, conduct regional and/or state surveys to determine projected job growth for technical professionals and paraprofessionals in the electronics and information technology industries.

Emerging Technology—Telecommunications

Background:

The telecommunications field, presently at $75 billion, will likely grow to $145 billion in the next few years. This growth will occur in the midst of "deregulatory confusion and technological change." University or industry groups, however, have not yet adequately addressed the need for new curricula and training to ensure a supply of qualified technical personnel who can respond to dynamic regulatory and technological change. Peter J. Boni, President and CEO of Summa Four, Inc., and 31 other company presidents have requested AEA's leadership in this area to help prevent "more significant market shifts to foreign communication systems competitors, such as NEC, Toshiba, etc."

AEA Action:

- Establish a task force to study the need for AEA action to develop with university deans telecommunications core curricula and continuing technical education courses.

Japan Fellowship Program (Electronics Education Foundation)

Background:

AEA began a pilot program this year through its Foundation to foster mutual appreciation of the technological capability of both the U.S. and Japan. Six American engineering and computer science graduate students completed nine weeks of Japanese language training at Cornell University funded by 12 AEA member companies. Students departed for Japan in Fall of 1984 and will spend three months to one year working in research labs at NEC, Oki, or Intel-Japan. All travel and living expenses are paid by host Japanese companies. U.S. Department of Commerce funds matched by AEA in-kind dollars pay for an on-site program coordinator at AEA's office in Tokyo. The program has been received enthusiastically by government, industry, and academia and merits expansion.

AEA Action:

- Raise money from U.S. companies and/or secure matching funds from federal sources and enlist increased Japanese company participation to expand present program to 12 students in fall of 1985.

Faculty Development Program (Electronics Education Foundation)

Background:

AEA's Electronics Education Foundation (EEF) program is focused on opening the major bottleneck in engineering education—a shortage of faculty. EEF has raised directly almost $7 million and tracked another $351 million going directly from member companies to engineering and CS departments.

Two years ago a goal was set to raise 200 fellowships to develop new faculty. To date 123 fellowships have been funded. Nineteen fellowships are likely to be pledged before year's end, leaving an additional 58 to be raised.

AEA Action:

- Form new AEA fundraising committees and help present ones set new goals to raise 58 more fellowships, 25 more faculty grants, and donations of instructional lab equipment and service contracts.

Federal Initiatives

R&D Tax Incentive Legislation

Background:

Both last and this year's Congress failed to enact the "High Technology Research and Scientific Education Act" (HR 4475 and S 2165). This cornerstone piece of AEA-developed legislation would make permanent the R&D tax credit scheduled to expire in 1985. Key components in the proposed bill will also improve engineering and technical education. Reintroduction of this legislation and strengthening of the political alliance established in 1984 between AEA, engineering deans, college presidents, and educational groups to achieve successful passage is a top priority.

AEA Action:

- Continue efforts to enact the "High Technology Research and Scientific Education Act" with key components:
  (1) Create a new 25 percent credit to encourage companies to contract for basic research with universities for amounts exceeding a fixed historical maintenance of effort floor;

(2) Expand present enhanced deduction for donation of new and customer-owned scientific and technical equipment and software three years or newer to higher education institutions for teaching and research purposes;
(3) Exclude from a student's IRS taxable income loans which are "forgiven" when a student graduates and teaches engineering, computer science, or science.

Funding for Fundamental Civilian-Oriented Engineering Research

Background:

While federal R&D funding has increased the last few years, over 70 percent of the increases are for defense-related applied research and development. Historically, less than 10 percent of NSF's budget has gone to fundamental engineering research.

AEA Action:

- Pursue increase of fundamental non-defense-related engineering research dollars through NSF.

NSF Fellowship-Match Program

Background:

In 1984 NSF enacted a five-year program to annually fund 200 "Presidential Young Investigators" (PYI) for up to $100,000 a year (includes industry funds) to conduct research. The intent is to aid retention and recruitment of scientific and engineering faculty.

The awards are restricted to faculty already teaching but with less than five years teaching experience. Assistance is needed to stimulate increased long-term industry dollar-support for PYI recipients. And, while the NSF-PYI Program assists those already teaching, it seems appropriate for NSF to match industry dollars to fund the production of new faculty as well.

AEA Action:

- Encourage AEA companies to provide long-term matching dollars for NSF's Presidential Young Investigators (PYI) program.
- Work to enact an NSF dollar-match program with industry for fellowships to produce new faculty.

National Engineering Research Agenda

Background:

Today, unlike 20 years ago, a fuzzy line exists between basic science and fundamental engineering research. As Dr. Don Glower, Dean of Engineering at Ohio State, points out, "The same research may be thought of as chemistry by a chemist and engineering by a chemical engineer. Similarly. . . research thought of as micro-electronics electrical engineering may appear to a physicist as solid state physics research on electronics properties." Despite similarities, differences in science and engineering bodies of knowledge and methodology require basic research in both the science and engineering communities.

The National Academy of Engineering's National Research Council has undertaken a study to define a National Engineering Research Agenda. The IEEE has been invited to organize committees of technical experts.

AEA Action:

- Organize a select group of AEA industry executives and provide input through IEEE into the National Engineering Research Agenda study.

State Initiatives

Tax Incentive Legislation

Background:

Modeled on AEA-developed federal R&D legislation, California enacted AB 430. AB 430 provides tax incentives to encourage research and instructional equipment donations to higher education institutions. AEA has played a key role in developing or improving various other related tax incentive legislation. These boiler-plate bills can be transported to other states, working through AEA Council Government Affairs Committees.

AEA Action:

- As requested by AEA Councils and where resources permit, assist states to enact tax legislation to improve engineering and technical education.

Alternate Salary System

Background:

The fact that new assistant engineering professors at public universities in 1983-84 earned on average $3,000 more than faculty in other disciplines demonstrates some awakening by state legislators and educational budgetary bodies to the growing engineering faculty crisis. Most recognize the equally intrinsic value of all faculty that

contribute to the production of well-rounded graduates. Too few, however, have faced the need to formally build in mechanisms that systematically trigger salary augmentation in any discipline—whether it be engineering or any other field—whenever market conditions create serious retention and recruitment problems.

A "same size salary fits all" approach ignores the growing severity of the engineering faculty situation. Annually, monies for hard-to-hire disciplines should be a separately negotiated budget line item. The problem should not be solved by dipping into salary "pots" negotiated appropriately and fairly for faculty across-the-board. Monies from this separate, hard-to-hire budget amount can be distributed to faculty within a discipline based on hard data such as student-to-faculty ratios, national salary comparisons by discipline (*not* institution to institution), ratio of foreign-born to U.S.-born faculty, ratio of part-time to full-time faculty, recruitment and retention history, number of near-term retirements, etc.

A long-term solution will be to separate out engineering faculty salary plans as is presently done with professional schools like medicine and law. Engineering—whether taught at a research or non-research institution—has several characteristics which liken it to professional schools: national accreditation, the need for updating of theory and practice by both faculty and student graduates, and a competitive market for holders of terminal degrees.

AEA Action:

- Pursue with increased emphasis state-by-state enactment of a built-in salary system which minimizes marketplace impact on engineering and computer science faculty retention and recruitment.

Community College Vocational Education

Background:

Improvement of community college vocational education comes generally through new legislation or educational policy changes. Through AEA staff's membership on the Board of Governors for the California Community Colleges and chairmanship of a statewide community college vocational education committee, various community college voc ed bills and policies have been and are being developed in three areas: (1) development of a Student Information System to report how many new students are being trained for which jobs; (2) assessment of voc ed instructors' needs to update skills and allocation of funds to provide such in-service; and (3) improvement of voc ed curriculum through increased industry participation on program advisory committees.

AEA Action:

- Pursue enactment of boiler-plate voc ed legislation in California for transport to other states at the request of AEA Councils and their Government Affairs Committees.

Glossary of Organizations and Terms

AAES	American Association of Engineering Societies
ABET	Accreditation Board for Engineering and Technology
ACM	Association for Computing Machinery
AMCEE	Association for Media-Based Continuing Education for Engineers
ASEE	American Society for Engineering Education
BLS	Bureau of Labor Statistics
CACI	Colorado Association for Commerce and Industry
CFAE	Council for Financial Aid to Education
CSU	California State University
CWETA	California Worksite Education and Training Act
ECFSP	Engineering College Faculty Shortage Project
EEF	Electronics Education Foundation
EMC	Engineering Manpower Commission
ERTA	Economic Recovery Tax Act of 1981
E-TEC	Engineering and Technical Education Committee
IEEE	Institute of Electrical and Electronic Engineers
IIAT	Institute for Innovative and Applied Technology
ITV	Instructional Television
JTPA	Job Training Partnership Act
MCC	Microelectronics and Computer Technology Corporation
MCSS	Market Condition Salary Supplement
MHTC	Massachusetts High Technology Council, or Minnesota High Technology Council
NASULGC	National Association of State Universities and Land Grant Colleges
NRC	National Research Council
NSF	National Science Foundation
PYI	Presidential Young Investigators
SIA	Semiconductor Industry Association
SRC	Semiconductor Research Corporation
UC	University of California
WCTA	Washington Council for Technology Advancement

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Addendum A

AEA Blue Ribbon Committee on Engineering Education

Committee Chairman
Dr. William J. Perry, *Partner*
Hambrecht and Quist

Dr. Richard Atkinson, *Chancellor*
University of California, San Diego

Dr. Joseph A. Boyd, *Chairman and CEO*
Harris Corporation

John M. Fluke, *Chairman*
John Fluke Manufacturing Company, Inc.

Dr. C. Lester Hogan, *Director and Consultant*
Fairchild Camera and Instrument Corporation

Dr. Robert N. Noyce, *Vice Chairman*
Intel Corporation

Dr. Joseph Pettit, *President*
Georgia Institute of Technology

Dr. Allen E. Puckett, *Chairman*
Hughes Aircraft

Ray Stata, *Chairman and President*
Analog Devices, Inc.

Dr. Dean A. Watkins, *Chairman*
Watkins-Johnson Company

Dr. Karl Willenbrock, *Green Professor of Engineering*
Southern Methodist University

John A. Young, *President and CEO*
Hewlett-Packard Company

Addendum B

Engineering and Technical Education Committee

Committee Chairman
Glenn E. Penisten, *Chairman*
AMI/Gould

Gene Chao, *Chairman and CEO*
Metheus Corporation

Jan J. Collmer, *President*
Collmer Semiconductor, Inc.

Mitchell E. Gooze, *President*
SoloSystems

Philip K. Hammond, *Chairman and CEO*
Dynamic Sciences, Inc.

Donovan B. Hicks, *Group Vice President*
Ball Corporation

Frederick R. Hume, *V.P., Planning and Technology*
John Fluke Mfg. Co.

Peter A. McCuen, *Chairman*
McCuen & Steele

Robert Noyce, *Vice Chairman*
Intel Corporation

Lois Rice, *Senior V.P., Government Affairs*
Control Data Corporation

William R. Thurston, *President*
GenRad, Inc.

Dr. Karl Willenbrock, *Green Professor of Engineering*
Southern Methodist University

John A. Young, *President and CEO*
Hewlett-Packard Company

Graham C.C. Miller, *Chairman and President*
LTX Corporation

Ex-Officio:
William Perry, *Chairman*
Electronics Education Foundation

Electronics Education Foundation

Chairman
William J. Perry, *Partner*
Hambrecht & Quist

Jan J. Collmer, *President*
Collmer Semiconductor, Inc.

E.E. Ferrey, *President*
American Electronics Association

Glenn E. Penisten, *Chairman*
AMI/Gould

William R. Thurston, *President*
GenRad, Inc.

Karl Willenbrock, *Green Professor of Engineering*
Southern Methodist University

Legislative Subcommittee

Barbara Bowen, *Director*
Apple Education Foundation

Philip K. Hammond, *President*
Dynamic Sciences, Inc.

Robert Kirkwood, *Director of Government Affairs*
Hewlett-Packard Company

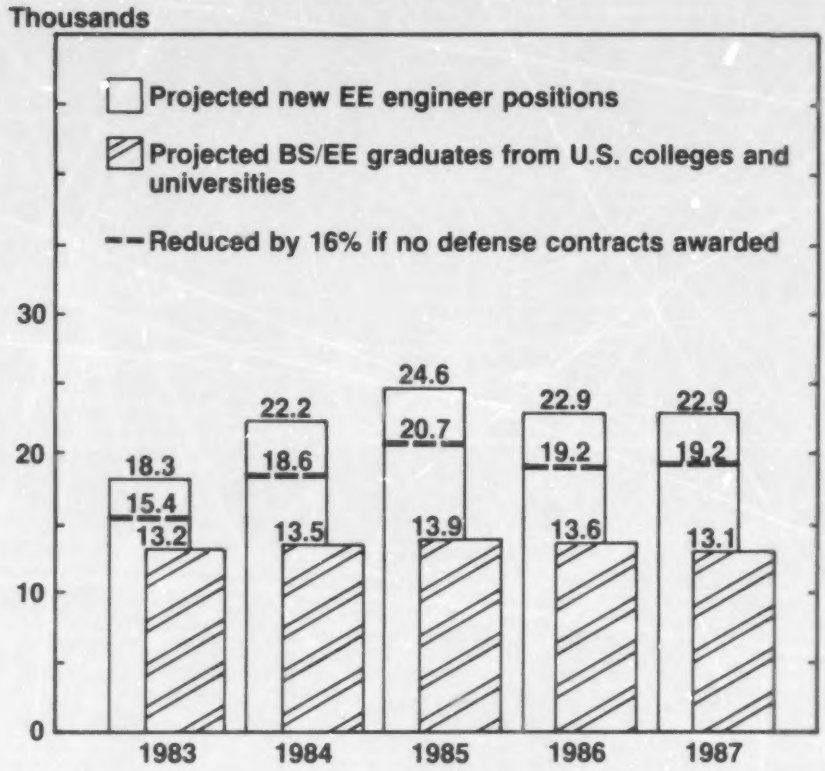
Lois Rice, *Sr. V.P., Government Affairs*
Control Data Corporation

Emil Sarpa, *Corporate Manager, Academic Relations*
Intel Corporation

James Johnson, *Manager Government Affairs*
Xerox Corporation

Addendum C

EE Engineer Supply and Demand



	1983–1987
Projected Need for EE Engineers	110,900
Projected New EE Grads	67,296
Projected Difference	43,604
Projected Difference (w/o defense)	25,860

Methodology to Compute Demand

1) EE demand figures are based on projected annual growth rate of 10.6% from 1983–1987. Data come from 815 electronics fac ties with combined annual sales of $56B. Based on these sales figures, AEA data reflect about 30% of the entire industry. Projections, therefore, are presented for the entire industry.

2) 10% of the industry projections are based on successful awarding of defense contracts. Therefore, demand projections have also been reduced by 16% based on a conservative scenario that no anticipated defense contracts will be awarded.

Methodology to Compute Supply

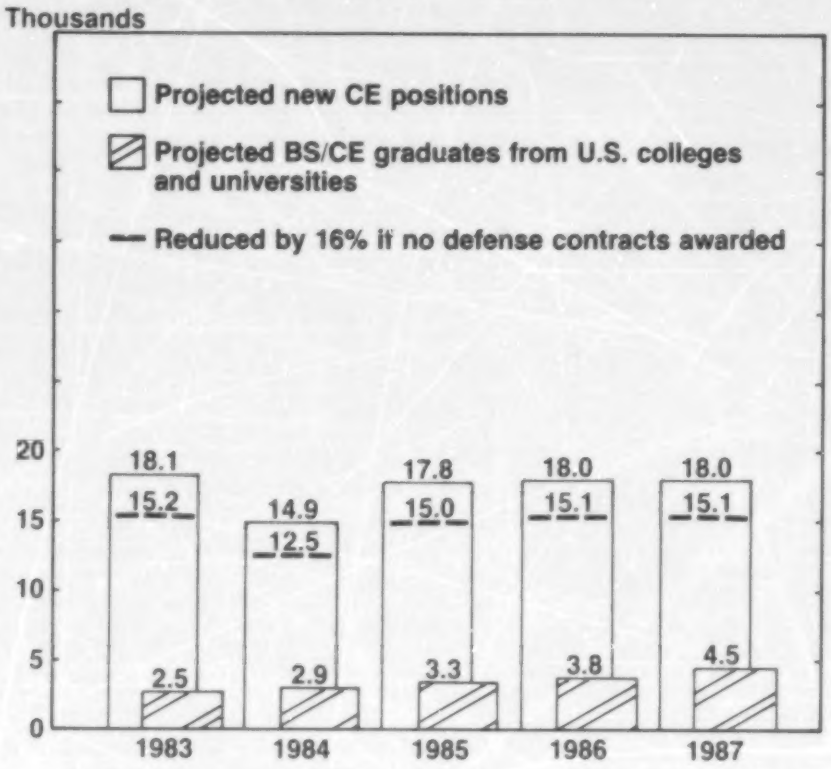
1) Projections of BS/EE degrees are from National Center for Education Statistics, which reports 2.4% annual growth through 1985, and 2.5% decrease annually from 1985–1990.

2) Projections reflect 80.2% of entire BS/EE grads, since NSF estimates that 80.2% of all engineers in the U.S. are employed in industry.

Source: AEA Projections Survey

Addendum D

Computer Engineer Supply and Demand



1983–1987	
Projected Need For CEs	86,762
Projected New CE Grads	16,960
Projected Difference	69,802
Projected Difference (w/o defense)	53,920

Methodology to Compute Demand

1) CE figures are based on projected annual growth rate of 16.5%. Data come from 815 electronics facilities with combined annual sales of $56B. Based on these sales figures, AEA data reflect about 30% of the entire industry. Projections, therefore, are presented for the entire industry.

2) 16% of the industry projections are based on successful awarding of defense contracts. Therefore, demand projections have also been reduced by 16% based on a conservative scenario that no anticipated defense contracts will be awarded.

Methodology to Compute Supply

1) Projections of BS/CE degrees are based on annual growth of 15.8% (the average annual increase of degrees awarded from 1977–1982). Degree projections assume, therefore, that U.S. colleges will continue to increase the number of BS/CE degrees awarded at the same rate as the past 5 years.

2) Projections reflect 80.2% of entire BS/CE grads, since NSF estimates that 80.2% of all engineers in the U.S. are employed in industry.

Source: AEA Projections Survey

Addendum E

U.S. Engineering Graduates

Number of Degrees
Electrical Engineers

Year	B.S.	M.S.	Ph.D.	Total
1970	11,921	4,150	873	16,944
1971	12,145	4,359	899	17,403
1972	12,430	4,352	850	17,632
1973	11,844	4,151	820	16,815
1974	11,347	3,702	700	15,749
1975	10,277	3,587	673	14,537
1976	9,954	3,782	644	14,380
1977	9,837	3,674	574	14,085
1978	10,702	3,475	524	14,701
1979	12,213	3,335	545	16,093
1980	13,594	3,660	523	17,777
1981	14,558	3,762	503	18,823
1982	16,094	4,186	549	20,829
1983	18,590	4,645	628	23,863

Annual % Change
Electrical Engineering

Year	B.S.	M.S.	Ph.D.	Total
1970	4.80	2.49	1.75	4.07
1971	1.88	5.04	2.98	2.71
1972	2.35	–0.16	–5.45	1.32
1973	–4.71	–4.62	–3.53	–4.63
1974	–4.20	–10.82	–14.63	–6.34
1975	–9.43	–3.11	–3.86	–7.70
1976	–3.14	5.44	–4.31	–1.08
1977	–1.18	–2.86	–10.87	–2.05
1978	8.79	–5.42	–8.71	4.37
1979	14.12	–4.03	4.01	9.47
1980	11.31	9.75	–4.04	10.46
1981	7.09	2.79	–3.82	5.88
1982	10.55	11.27	9.15	10.66
1983	15.51	10.97	14.39	14.57

Number of Degrees
Computer Engineers

Year	B.S.	M.S.	Ph.D.	Total
1970	139	185	34	358
1971	174	250	44	468
1972	359	627	83	1,069
1973	568	589	96	1,253
1974	727	723	83	1,533
1975	599	678	107	1,384
1976	796	718	90	1,604
1977	1,280	802	136	2,218
1978	1,546	986	123	2,655
1979	1,510	1,074	190	2,774
1980	1,816	1,262	159	3,237
1981	2,356	1,294	171	3,821
1982	2,666	1,365	129	4,160
1983	2,643	1,419	102	4,164

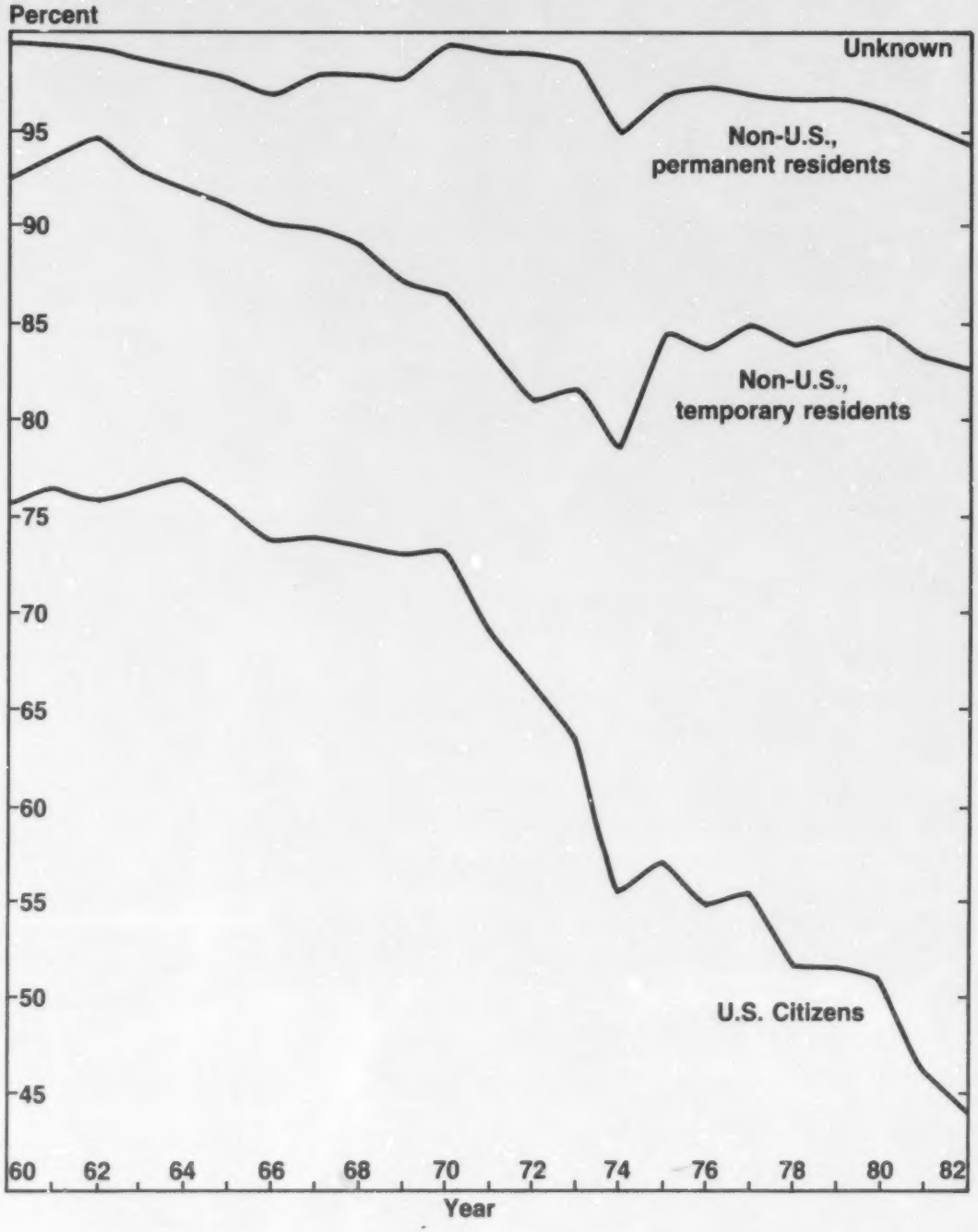
Annual % Change
Computer Engineers

Year	B.S.	M.S.	Ph.D.	Total
1970	167.31	54.17	54.44	84.54
1971	25.18	35.14	29.41	30.73
1972	106.32	150.80	88.64	128.42
1973	58.22	–6.06	15.66	17.21
1974	27.99	22.75	–13.54	22.35
1975	–17.61	–6.22	28.92	–9.72
1976	32.89	5.90	–15.89	15.90
1977	60.80	11.70	51.11	38.28
1978	20.78	22.94	–9.56	19.70
1979	–2.33	8.92	54.47	4.48
1980	20.26	17.50	–16.32	16.69
1981	29.74	2.54	7.55	18.04
1982	13.16	5.49	–24.56	8.87
1983	–.86	3.96	–20.93	.09

Source: Engineering Manpower Commission

Addendum F

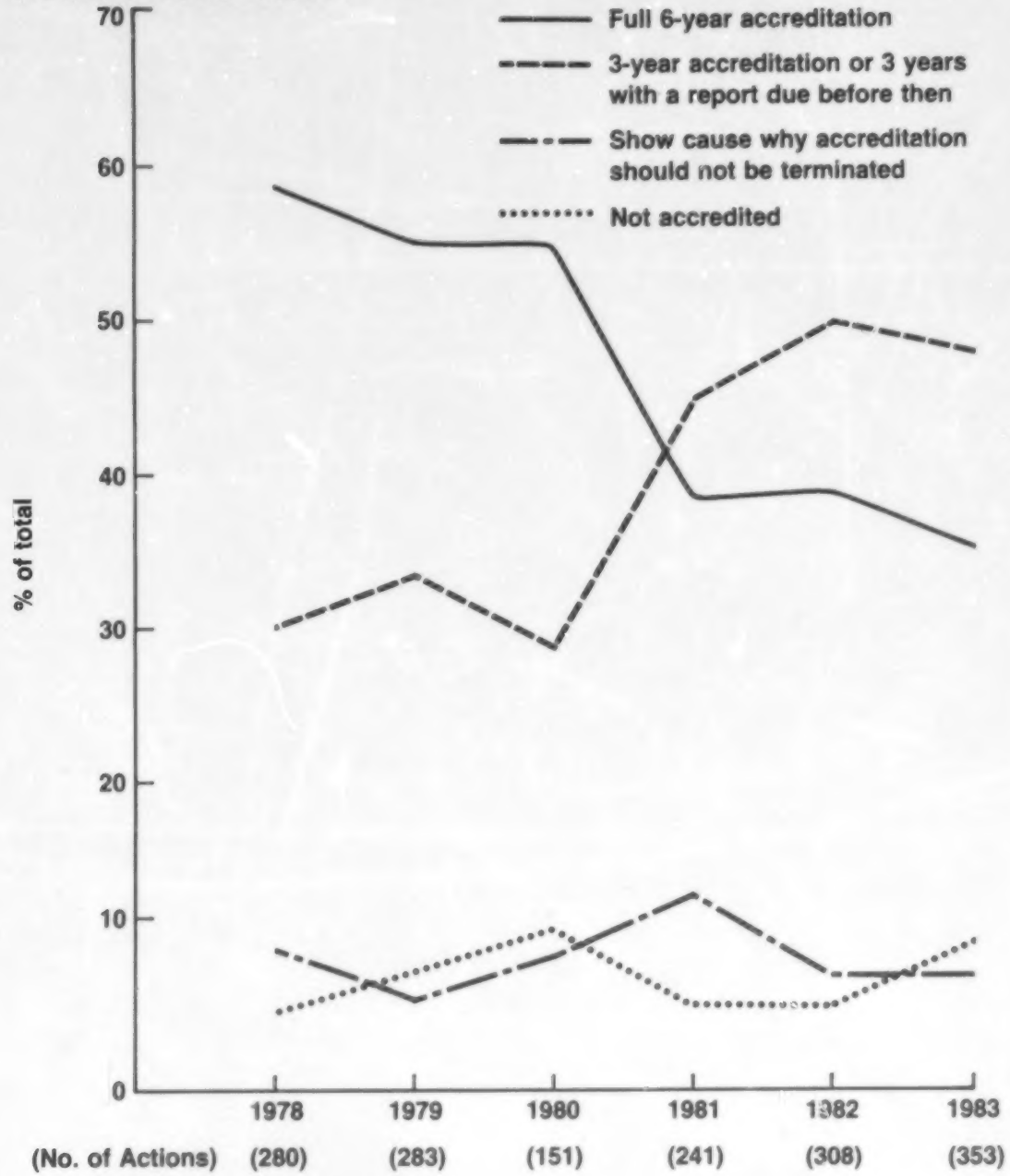
Citizenship Status of Engineering Doctorates



Source: National Science Foundation (NSF 83-328) and National Research Council

Addendum G

Undergraduate Engineering Accreditation Actions 1978–1983



Source: Accreditation Board for Engineering and Technology (ABET), 1983.

Addendum H

Research and Development Performance by Sector: 1953, 1960, and 1965–84

(Dollars in millions)

Current dollars

Year	Total	Federal Government	Industry	Universities and colleges	Associated FFRDCs	Other nonprofit institutions
1953	5,124	1,010	3,630	255	121	108
1960[1]	13,523	1,726	10,509	646	360	282
1965[2]	20,044	3,093	14,185	1,474	629	663
1966	21,846	3,220	15,548	1,715	630	733
1967	23,146	3,396	16,385	1,921	673	771
1968	24,605	3,494	17,429	2,149	719	814
1969	25,631	3,503	18,308	2,225	725	870
1970	26,134	4,070	18,067	2,335	737	916
1971	26,676	4,228	18,320	2,500	716	912
1972	28,477	4,590	19,552	2,630	753	952
1973	30,718	4,762	21,249	2,884	817	1,006
1974	32,864	4,911	22,887	3,033	865	1,179
1975	35,213	5,354	24,187	3,409	987	1,276
1976	39,018	5,769	26,997	3,729	1,147	1,376
1977	42,783	6,012	29,825	4,067	1,384	1,495
1978	48,129	6,811	33,304	4,625	1,717	1,672
1979	54,933	7,417	38,226	5,361	1,935	1,994
1980	62,618	7,632	44,505	6,080	2,246	2,175
1981	71,912	8,425	51,858	6,818	2,486	2,325
1982	80,317	9,141	59,011	7,261	2,479	2,425
1983 (est.)	87,678	10,228	64,600	7,675	2,600	2,575
1984 (est.)	96,975	10,800	72,000	8,605	2,770	2,800

Constant dollars[3]

Year	Total	Federal Government	Industry	Universities and colleges	Associated FFRDCs	Other nonprofit institutions
1953	8,677	1,892	6,171	428	203	183
1960[1]	19,635	2,481	15,297	928	517	412
1965[2]	26,896	4,124	19,077	1,965	838	892
1966	28,442	4,183	20,256	2,229	819	955
1967	29,241	4,276	20,725	2,417	848	975
1968	29,833	4,248	21,116	2,612	874	985
1969	29,586	4,065	21,094	2,582	842	1,003
1970	28,613	4,481	19,756	2,564	809	1,003
1971	27,814	4,422	19,081	2,613	749	949
1972	28,477	4,590	19,552	2,630	753	952
1973	29,147	4,559	20,094	2,762	781	950
1974	26,763	4,383	19,889	2,696	772	1,023
1975	26,153	4,344	19,229	2,766	801	1,013
1976	29,510	4,374	20,400	2,828	870	1,038
1977	30,506	4,271	21,297	2,889	983	1,066
1978	32,002	4,530	22,142	3,075	1,142	1,113
1979	33,612	4,537	23,391	3,279	1,184	1,221
1980	35,133	4,286	24,944	3,411	1,265	1,217
1981	36,859	4,321	26,575	3,497	1,275	1,191
1982	38,742	4,379	28,524	3,478	1,188	1,173
1983 (est.)	40,508	4,807	29,957	3,526	1,194	1,194
1984 (est.)	42,961	4,758	31,944	3,788	1,219	1,244

[1]Data for 1954–59 can be found in *National Patterns of R&D Resources, 1953–1977* (NSF 77-310).
[2]Data for 1961–64 can be found in *National Patterns of Science and Technology Resources, 1981* (NSF 81-311).
[3]Based on GNP implicit price deflator.

Source: *National Patterns of Science and Technology Resources 1984*, NSF (84-311), p. 32.

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Addendum I

AEA Regional Electronics Education Committees

Each regional committee is a group of six to ten corporate executives who were selected because of their concern about the shortage of electrical/computer engineers and their willingness to help solve the problem.

No educators or government people are members of the committees, although they may be invited to selected meetings. Since no one educator can represent more than his or her own institution, this restriction helps ensure that industry sets priorities for assisting colleges and universities as objectively as possible.

Regional Committee Chairs

Colorado

Don Hicks
Group Vice President
Ball Corporation

Connecticut

Paul Yoder, Jr.
Assistant to Director of Research
Perkin-Elmer, Optical Group

Los Angeles

Philip Hammond
President & CEO
Dynamic Sciences, Inc.

Massachusetts

Graham C.C. Miller
Chairman & President
LTX Corporation

Minnesota

John A. Rollwagen
Chairman of the Board
Cray Research, Inc.

New Jersey

James Gallo
R&D Manager
Hewlett-Packard

New York

Len Borow
President
Comstron Corp.

Orange County

Walter J. Kane
President
Applied Data Communications

Oregon

Kenneth M. Patton
General Manager
Hewlett-Packard Company

Sacramento

Pete McCuen
President
McCuen & Steele, Inc.

San Diego

Terry Bibbens
President
Loral Instrumentation

San Francisco

Al Stein
Chairman & CEO
VLSI Technology, Inc.

Santa Barbara

J.L. Farnsworth
Vice President
Santa Barbara Research Center

Texas

Warren Hogan
President
AirBorn, Inc.

Washington

Robert H. Ilgenfritz
V.P. & General Manager
Sunstrand Data Control

Addendum J

Electronics Education Foundation

Summary

October 3, 1984

To date, AEA's Electronics Education Foundation (EEF) has received commitments for engineering education faculty and equipment needs totalling $6,340,428.

Fellowship-Loans: to support graduate education of U.S. citizens who intend to get Ph.D.s and teach engineering; 69 fellowship-loans have been committed through EEF by 48 companies and individuals to 29 universities	$ 3,230,288
Note: Hewlett-Packard is funding an additional 54 AEA fellowship-loans at a total cost of $6 million.	
Faculty Grants: to help universities retain and recruit engineering professors; 71 faculty grants have been committed through EE by 56 companies and individuals to 27 colleges	$ 725,175
Equipment Purchase Grants: to help universities purchase, repair, or service instructional laboratory equipment; 22 equipment grants have been committed through EEF by 14 companies to 13 universities	$ 249,191
Equipment: 2 companies have made 4 equipment donations through EEF	$ 465,000
Matching Grants: The AEA Oregon Council has raised funds on a dollar-for-dollar match with Oregon Legislature funds for a variety of higher education initiatives in the state	$ 1,310,974
Japan Fellowships: to sponsor U.S. graduate students doing research in Japan. 12 companies have committed funds.	$ 18,000
Student Aid: 4 companies have committed funds for student aid	$ 205,200
17 companies have committed through EEF grants unrestricted as to purpose and university designation	$ 31,600
Operating Grant: AEA General Funds	$ 105,000
TOTAL	**$ 6,340,428**

The Foundation serves a leadership role in stimulating the flow of monies — recommended as 2 percent of each company's R&D expenditures — directly to universities for engineering education purposes. Data on such direct contributions, recognized as a fraction of those actually given, show some $353 million donated.

AEA ELECTRONICS EDUCATION FOUNDATION

Companies and Individuals Contributing to Date

ACC	Santa Barbara	CA
Acurex Corporation	Mountain View	CA
Advanced Micro Devices, Inc.	Sunnyvale	CA
Airborn, Inc.	Addison	TX
Analog Devices, Inc.	Norwood	MA
Applied Data Communications	Tustin	CA
Applied Microsystems Corp.	Redmond	WA
Argosystems, Inc.	Sunnyvale	CA
Arnav Systems, Inc.	Salem	OR
Arthur Andersen & Company	Portland	OR
Atari, Inc.	Sunnyvale	CA
Augat, Inc.	Mansfield	MA
Avantek, Inc.	Santa Clara	CA
Avtech Corporation	Seattle	WA
Azurdata, Inc.	Redmond	WA
BR Communications	Sunnyvale	CA
Banctec, Inc.	Dallas	TX
Benhard, Gordon F.	Santa Ana	CA
Biamp Systems, Inc.	Beaverton	OR
Black & Company, Inc.	Portland	OR
Bolliger, Hampton & Tarlow	Portland	OR
C-Cor Electronics	Beaverton	OR
Cable Howse & Cozadd	Bellevue	WA
Caddex Corporation	Woodinville	WA
CalBag Metals	Portland	OR
California Microwave, Inc.	Sunnyvale	CA
Chernoff, Vilhauer, McClung, Birdwell & Stenzel	Portland	OR
Cherry Electrical Products	Waukegan	IL
Coherent, Inc.	Palo Alto	CA
Collmer Semiconductor, Inc.	Dallas	TX
ComDesign, Inc.	Goleta	CA
Communications Industries, Inc.	Dallas	TX
Compugraphic Corporation	Wilmington	MA
Computer Language Research	Carrollton	TX
Computervision Corporation	Bedford	MA
Convergent Technologies	Santa Clara	CA
Coopers & Lybrand	Portland	OR
Coopers & Lybrand	Seattle	WA
Corboy, Michael R.	Dallas	TX
Cox, Fred B. & Harriet F.	Costa Mesa	CA
Cullinet Software, Inc.	Westwood	MA
D. Ray Whitson & Associates	Dallas	TX

DMA Systems	Goleta	CA
Dalmo Victor Operations	Belmont	CA
Data Design Laboratories	Cucamonga	CA
Data I/O Corporation	Redmond	WA
Data Printer Corporation	Malden	MA
Datapower, Inc.	Santa Ana	CA
Dataproducts Corporation	Woodland Hills	CA
Davis, Wright, Todd, Riese	Bellevue	WA
Deloitte Haskins & Sells	Portland	OR
Digital Equipment Corporation	Maynard	MA
Digital Switch Corporation	Richardson	TX
Dionex Corporation	Sunnyvale	CA
EG&G, Inc.	Wellesley	MA
Eeco, Inc.	Santa Ana	CA
Electro Scientific Industries	Portland	OR
Electronic Controls Design, Inc.	Mulino	OR
Electronics Diversified, Inc.	Hillsboro	OR
Electrospace Systems, Inc.	Richardson	TX
Ernst & Whinney	Seattle	WA
FEI Company	Hillsboro	OR
FMC Foundation	Chicago	IL
Finnigan Corporation	San Jose	CA
First Interstate Bank	Portland	OR
Flexible Computer Corporation	Dallas	TX
Floating Point Systems, Inc.	Beaverton	OR
Ford Aerospace & Communications Corp.	Palo Alto	CA
Foundation of the Litton Industries	Beverly Hills	CA
Genrad Foundation	Concord	MA
George Quist Fellowship Fund	San Francisco	CA
Girard Capital	San Diego	CA
Gould AMI	Santa Clara	CA
Graham & James	San Francisco	CA
Granger Associates	Santa Clara	CA
Granville-Phillips Company	Boulder	CO
Gulton Industries, Inc.	Princeton	NJ
Hensway, Inc.	Corvallis	OR
Hewlett-Packard Company	McMinnville	OR
Honeywell Marine Systems	Seattle	WA
Honeywell, Inc.	Minneapolis	MN
Huntron Instruments	Lynnwood	MA
IRT Corporation	San Diego	CA
Informatics General Corporation	Woodland Hills	CA
Intecom, Inc.	Allen	TX
Integrated Circuits, Inc.	Bellevue	WA
Intel	Hillsboro	OR
Interamics	San Diego	CA
Intermec Corporation	Lynnwood	WA

Jackson, Vernon D.	Dallas	TX
John Fluke Mfg. Co., Inc.	Everett	WA
Kentrox Industries, Inc.	Portland	OR
Kevex Corporation	Foster City	CA
Kleist, Robert A.	Irvine	CA
Kollmorgen Corporation	Stamford	CT
Kyocera International, Inc.	San Diego	CA
LTX Corporation	Westwood	MA
Leach Corporation	Buena Park	CA
Lear Siegler, Inc.	Anaheim	CA
Leupold & Stevens, Inc.	Beaverton	OR
Lindsay, Hart, Neil & Weigler	Portland	OR
Magnetic Controls Company	Minneapolis	MN
Magretech, Inc.	Goleta	CA
Main Hurdman	Portland	OR
Management Assistance, Inc.	New York	NY
Mann, Russell I., Jr.	Santa Clara	CA
McKeen Melancon	Dallas	TX
Met One, Inc.	Grants Pass	OR
Metheus Corporation	Hillsboro	OR
Micro Peripherals, Inc.	Chatsworth	CA
Micropac Industries, Inc.	Garland	TX
Mitsubishi Consumer Electronic	Santa Ana	CA
Motorola, Inc.	Phoenix	AZ
NCHEMS	Boulder	CO
Newport Electronics, Inc.	Santa Ana	CA
Northrop Corporation	Los Angeles	CA
Northwest Instrument Systems	Portland	OR
OECO Corporation	Portland	OR
Ochsner, Frederick	Dallas	TX
Optical Coating Laboratory, Inc.	Santa Rosa	CA
Oregon Economic Action Council	Portland	OR
Pacer Corporation	Woodinville	WA
Pacific Systems Corporation	Seattle	WA
Peat, Marwick, Mitchell & Company	Portland	OR
Penisten, Glenn E.	Santa Clara	CA
Perkin-Elmer Corporation	Norwalk	CT
Price Waterhouse	Portland	OR
Printronix, Inc.	Irvine	CA
Quantum Corporation	Milpitas	CA
Quinton Instrument Company	Seattle	WA
RF Monolithics	Dallas	TX
Raychem Corporation	Menlo Park	CA
Recognition Equipment, Inc.	Irving	TX
Rediffusion Simulation, Inc.	Arlington	TX
RepublicBank Corporation	Dallas	TX
SOLOSystems	San Jose	CA

Santa Barbara Research	Goleta	CA
Sea-Fab, Inc.	Redmond	WA
SeaMed Corporation	Redmond	WA
Seattle-First National Bank	Seattle	WA
Sentrol Inc.	Portland	OR
Sequent Computer Systems, Inc.	Portland	OR
Servio Logic Corporation	Portland	OR
Shaw Venture Partners	Portland	OR
Sidereal Corporation	Portland	OR
Silicon Systems, Inc.	Tustin	CA
Simmonds Precision Products	Tarrytown	NY
Spencer Stuart & Associates	Dallas	TX
Stanford Telecommunications	Santa Clara	CA
Stoel, Rives, Boley, Fraser & Wyse	Portland	OR
Stover, Jerry	Dallas	TX
TDC Defense Systems Group	Arlington	TX
Tektronix, Inc.	Beaverton	OR
TelAmerica, Inc.	Mountain View	CA
Telematic Products, Inc.	Redmond	WA
Terra Technology	Redmond	WA
The Strayton Corporation	Dallas	TX
Thiel, Gloria	Dallas	TX
Touche Ross & Company	Portland	OR
U.S. Alpha	Grand Prairie	TX
UCCEL	Dallas	TX
Unisystems International Inc.	Dallas	TX
Unitrode Corporation	Lexington	MA
VLSI Technology, Inc.	San Jose	CA
VMX, Inc.	Richardson	tX
Varo, Inc.	Garland	TX
Verbatim Corporation	Sunnyvale	CA
Vitatek, Inc.	Hillsboro	OR
Wacker Siltronic Corporation	Portland	OR
Wang Laboratories, Inc.	Lowell	MA
Western Transformers, Inc.	Portland	OR
William O. Hunt Investments	Dallas	TX
Wiltron Company	Mountain View	CA
Xytec Corporation	Bend	OR

Addendum K

CALIFORNIA STATE UNIVERSITY LONG BEACH

Office of the Associate Dean for Instruction
School of Engineering
(213) 498-5123
December 2, 1983

Ms. Pat Hill Hubbard
President
Electronics Education Foundation
2680 Hanover Street
Palo Alto, CA 94304

Dear Ms. Hubbard:

May I please take this opportunity to express my appreciation for all the help you and the Electronics Education Foundation have provided in the form of financial support to our engineering program at California State University, Long Beach. With our engineering enrollment approaching 5,000 students, we are in great need of help, and your contributions have made a significant difference to the quality of our program. At California State University, Long Beach, the School of Engineering currently has six departments. They are as follows: Civil Engineering; Chemical Engineering; Computer Science and Engineering; Electrical Engineering; Mechanical Engineering; and Industrial Technology. Our newest department is the Computer Science and Engineering Department, and it is currently in its first stages of formulation.

The purpose of this letter is to provide a brief statement indicating the use of funds provided by Applied Data Communications.

According to the letter of February 28, 1983, we have allocated $2,500 to Dr. Stanley Wolf, $2,500 to Dr. Christopher Druzgalski; $2,500 to Dr. Radhe Das; and $2,500 to expand on our Computer Graphics Laboratory. These seed funds have been extremely helpful to us in that they have encouraged other companies to match these funds and beyond to expand our laboratories.

Dr. Stanley Wolf was provided with $2,500 as a fellowship to help him develop a computer aided VLSI design capability for the School of Engineering. He has spent countless hours working with companies and developing this area of expertise. This initial funding has allowed him to expand his capabilities to the point where he has brought in a $20,000 grant from Dupont Corporation to investigate new types of chip fabrication materials.

Dr. Christopher Druzgalski used his $2,500 as fellowship support and for equipment supplies. His objective was to implement CAD software on microcomputers. His work incorporated computer aided digital logic design and analysis as well as complex circuit design and analysis into our curriculum. Motorola Corporation, as a result of his work, has recently awarded him 12 Motorola 68000 Microprocessor Developmental Stations. These stations will be used to significantly enhance our Microprocessor Laboratory.

Dr. Radhe Das received $2,500, and these funds were used for both fellowship support and equipment purchases. He has used his funds to expand in our Power and Electronic Laboratory and is currently negotiating a possible grant from JPL to investigate solar cell development.

The last $2,500 was used to complete the installation of our HP 1000 Computer Graphics Laboratory. We were able to purchase a color controller valued at $14,000 for only $4,000. We raised $4,000 by using your $2,500 and another $1,500 from the Fluor Corporation. The acquisition of a $14,000 video color controller has allowed our HP 1000 to generate color video images on a high resolution monitor with a resolution of 1,000 by 1,000 in color. This type of equipment has greatly enhanced our Graphics Laboratory and it has the potential for producing students with current state-of-the-art expertise.

I believe that the $10,000 has been used to significantly help our program in Electrical Engineering and Computer Science. In addition, these funds have helped us to bring in additional grants and donated equipment such that the initial $10,000 has been enlarged to $40,000. We are deeply indebted to Applied Data Communications for their help and for your support in this matter.

Sincerely yours,

Morton D. Schwartz
Acting Associate Dean for Instruction
School of Engineering

MDS: dp

cc: Dean Williams
Walter Kane